

METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER)

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

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Instrumentation of British Industry

THERE are very few modern production processes for which instruments of one kind or another are not essential. In many cases they provide information upon which efficient operation is based, and the cost of the necessary equipment is almost invariably trivial when compared with the economy attained and uniformity of results obtained by the use of appropriate instruments. In some of the older factories there seems to be a reluctance to instal instruments; the view being sometimes expressed that they are too delicate and complicated for the particular process. Whatever truth there may have been in this view in the past, advances that have been made in recent years in the design and construction of instruments ensures for them continuous work and reliable results. That this fact is appreciated to some extent is indicated by the great increase in the application of automatic controllers and recorders for laboratory and industrial purposes; however, there is much truth in a recent statement by Sir Frank Smith that the importance of instruments in the progress of scientific knowledge, in the quantity production of goods of many kinds, and in the maintenance of a uniform standard of quality, is not sufficiently realised in this country either by industry or by the Government. Sir Frank went further and suggested that their importance is not fully appreciated by many technicians and scientists. The occasion was a joint conference, convened by the Institution of Chemical Engineers, the Institute of Physics, and the Chemical Engineering Group of the Society of Chemical Industry, the object of which was to promote the interchange of knowledge between those using automatic controllers and recorders in different fields and to encourage collaboration between physicists and chemical engineers.

This reflection upon many technicians and scientists is probably due to the attention being directed to the results achieved, whether in the laboratory or in industry, rather than on the instruments used to obtain them. In some cases remarkable results are achieved with very inferior tools, but, as a rule, more uniform results of a high order and greater achievements are obtained the better the tools or instruments, provided they are used to the best advantage. Sir Frank cited the recent developments of radar and of the atomic bomb neither of which could have been achieved without instruments. The principles on which radar are based were enumerated by Clerk Maxwell more than half a century ago, but principles are neither instruments nor machines, and no developments were possible until instruments of an entirely new kind were invented. Radar would be impossible without an instrument to measure intervals of time smaller than a millionth of a second. Many decades ago J. J. Thomson produced the first instrument which made this possible—the cathode ray tube. This subsequently became the cathode ray oscillograph. By

development it became the eye of the television camera and was also used as the screen for most television receivers. The part of the radio valve in the development of radar should not be overlooked. The wireless valve was the development of an instrument—the one-way rectifier of Sir Ambrose Fleming. Without such instrumental developments as those of the cathode ray tube and the rectifying valve there could have been no radar.

The atom bomb has resulted from a study of nuclear physics, and it is certain, as Sir Frank pointed out, that there could not have been much advance in our knowledge of the atom without the cloud track apparatus invented by C. T. R. Wilson and the mass spectrograph of F. W. Aston. Rutherford did much of his research work with Wilson's cloud chamber, and always he was full of praise of the instrument which served him so well. To Aston's beautiful mass spectrograph we owe our knowledge that when transmutation of one element to another takes place there is a change in mass. The mass that disappears is converted into energy. Without instruments of this type it is extremely doubtful whether the liberation of atomic energy would ever have been achieved.

The discovery of X-rays just fifty years ago provided an instrument for examining the structure not only of the human body but of all kinds of materials including metals. To-day, few important components are built into an aeroplane until they have passed the searching scrutiny of the X-ray beams. Elsewhere in this issue reference is made to its use in the examination of steel castings. This discovery set in motion an era of physical research which has brought us the liberation of atomic energy. By means of X-ray crystallography it is possible to determine how the different atoms are arranged in the various substances which industry has to use, from which information can be obtained of their behaviour.

Nearly every big advance in industry is the result of knowledge obtained in the first place by the use of a new instrument. Those who have studied the history of the steam engine know that it was the indirect result of a study of the barometer, from which it was learned that the air had weight and exerted a pressure on the ground. It was this knowledge that led men to invent atmospheric steam engines which subsequently developed into steam expansion engines. To-day, there is no main feature of this country's life but what is dependent in some form or other on instruments. Instruments are now the eyes and ears of all progressive industries; we depend on them for the satisfactory supply of gas, electricity, water, the transportation of food and many other services. In war instruments this country has done wonders, especially in the development of those operating on electronic principles. But the main objective of the joint conference, previously referred to, and of the address by Sir Frank Smith, was to urge upon the big industrialists of this country the need for increased instrumentation of their industries.

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No one who has studied the returns of the Board of Trade and examined the quality of the products made in this country and abroad can doubt that if we are to have a large and prosperous export trade we must turn out articles of exceptional quality and at competitive prices. In the main these articles may be placed in two categories. The first, those which can be manufactured by mass production methods, and the second, special products. It is to the first category that instrumentation more directly applies—to products which are in demand in large quantities and which can readily be produced by mass-production methods. Such methods lead to greater uniformity in quality, little waste, greater use and cheaper cost. To produce such articles cheaply and at the same time to make them attractive and of high

quality, it is necessary to have big industrial units for their production and there must be control of the manufacturing operations by instrumentation.

The British instrument industry is in a much better position to-day than it was at the end of the last war, but it is a key industry and it is hoped that in the near future the Government will take appropriate steps to ensure that it is established on a firm basis and in a position to meet peace-time needs. The Government has urged industry to be more scientifically minded and it has stated with no lack of emphasis that if we are to maintain a decent standard of living we must increase our export trade. To achieve this, quality and low cost of products must be primary considerations and these necessitate equipment and instruments of high order.

Coke Oven Practice and Products

VICTORY in the field for the Allied Forces has been assisted in a substantial measure by the intensity of industrial effort during the war years, and we must now devote our skill and energy to the urgent task of restoring those conditions of proficiency which bring prosperity. This view was expressed by Mr. W. Neville Warwick in his Presidential Address at the recent annual meeting of The Coke Oven Managers' Association in which he discussed many aspects of the Association's work in a vigorous and stimulating manner. He referred especially to the manner in which coke oven staffs had worked during the war years. General shortage of experienced labour caused problems of an unprecedented character at a time when increased production and closer scientific control of analytical detail had to be given equal attention. The burdens were made heavier by the need for parsimonious renewal expenditure, a critical dissection of operating costs—statistical control and enforced utilisation of classes of coal not in conformity with normal practice.

Surveying design development since 1928, Mr. Warwick considered that after the introduction of American and Continental designs to increase productivity of the coke oven, production specialists have concentrated insufficient effort to protect the operator from the more uncomfortable features of the coking process. In general design there has been no great departure from pre-war practice as the time has been inopportune for radical changes. Coke oven technicians do know that present performance of the auxiliaries is not good enough and it seems we should foster deviation from the design that was considered fairly efficient up to the year 1938. We have had cause to lament the lack of flexibility and hard wearing propensities of equipment on modern ovens, especially evident when the ovens pass a life of 13 years. Now is the time for another step forward.

If industrial progress is to continue, standards of efficiency will increase, and specifications of products may become more severe to suit special manufacturing conditions in new trades. Development in other industries may eventually call for something near a non-variable metallurgical coke, and such a consistent product could hardly be made with the type of equipment operated to-day; new methods are required. The problem is very complex since if a plant is found capable of producing a precision quality of metallurgical or special coke, it is also desirable that it should control closely the quality and yield of gas, tar, sulphate,

benzole, and the miscellaneous derivatives attached thereto, which are all released initially under the same circumstances.

Renewed attention is being focussed on the subject of chemical utilisation and production of organic compounds from coke oven gas. Evidence of passing beyond the theoretical stage is shown by the active consideration being given to ethylene extraction and the initiative of firms who are installing specialised plant. With the technical brain power at this country's disposal we might organise ourselves and work alongside the American petroleum industry to some advantage. It is for us to decide now if we intend to stop at ethylene recovery, or go a stage further to the partial separation of methane. Is the total fractional separation of all the constituents by means of liquefaction too ambitious, at this stage? If this is so it is still necessary for us to keep the subject under active review when building or modernising recovery plant. It is advisable to prepare for the possible inclusion of such plant at a later date.

In the case of extracting ethylene from coke oven gas it is thought that ultimately alcohol will not be the object in view, but rather the production of the more remunerative bodies of which fifty are possible, e.g., vinyl chloride, ethylene dichloride, ethylene glycol, etc. The possible production of alcohol and its vast expanding demand does make the proposition more promising. Initial concentration of the ethylene in gas is of prime importance to the economic production of any synthetic chemical and the concentration in coke oven gas must be considered low compared with gases from other sources now being produced in Britain, such as cracked petroleum gas and those obtained via hydrogenation and cracking. Of the various methods of recovery direct adsorption in solvents, in chemicals with which it reacts, liquefaction or carbon adsorption, the latter two seem more applicable due to the necessity for initial concentration. The carbon adsorption process can produce ethylene some 98.5% pure, but if it is our desire to go further than producing liquid ethylene, then we would do well to consider liquefaction as this makes itself attractive in that we can have as well as ethylene a partial separation of the methane.

It has only been possible to refer to some aspects of Mr. Warwick's address, many of which will be familiar to coke oven managers but not adequately appreciated by many others. The time seems to be opportune to explore the possibilities likely to result from development in the design and operation of modern coke ovens and the use of ancillary plant to obtain the maximum profit from our main raw material.

The Manufacture of Seamless Steel Tubes

By J. W. Jenkin, Ph.D., B.Sc., A.R.I.C.

Director of Research, Tube Investments, Ltd.

The application of seamless steel tubes in many industries has made great progress in the last twenty years. Tubular products are especially useful for conveying gases or liquids and metallurgical developments have contributed to the improvement of steels for special seamless tubes for many industries, including the oil-refining, chemical, and high-pressure steam industries; they are also being used in increased quantities for structural purposes because they combine maximum stress carrying capacity with minimum weight. Practically all the regular carbon and alloy steels may be used in the seamless process; the chromium steels containing from 1 to 30 per cent. chromium and numerous other alloyed steels containing chromium with additions of such elements as molybdenum, nickel, manganese, silicon and titanium, are included in those successfully processed. Hot rolling operations provide the bulk of seamless tubes for ordinary requirements, but, when greater accuracy, high physical properties, better surfaces, thinner walls and small diameters are required, the tubes are cold drawn as a finishing operation. The various operations in seamless steel tube manufacture were described by the author in a lecture before the Sheffield Society of Engineers and Metallurgists in February last, to whom we are indebted for permission to publish here the main features presented.

INTRODUCTION

A SEAMLESS tube is one whose shape does not depend on leaving or making a joint, or closing a previously existing seam, i.e., it is a tube without discontinuity at any stage of its manufacture. The alternative terms "solid drawn" and "weldless" are also quite well understood, but are rather to be discouraged on grounds of inaccuracy. A tube is not a solid, for by definition it has a hole from end to end, and moreover it is not necessarily drawn: it may be rolled, pushed, kneaded, pulled, or extruded. "Weldless" must mean "without a weld," so apart from confusion with the spoken word welded, there is the gross error that a tube without a weld is not necessarily seamless. For instance, a riveted chimney stack is literally a "weldless" steel tube. Similarly, when a strip is formed into the tubular shape and not even welded, brazed, soldered, or the edges stuck together in any way, the result is a "weldless" steel tube, like some forms of electrical conduit that the trade knows as "close joint." Thus the correct term for the class of tube described herein is surely *seamless*. This means that instead of taking a hole and putting steel round it, one has to make the hole. That might rightly include the simple, slow, and costly expedient of drilling a hole along the axis of a cylindrical bar; but when it comes to the variety and extent of modern demand, the answer is a mechanical engineering industry that for the sake of mass production must make the hole rapidly under conditions when the steel is most amenable to

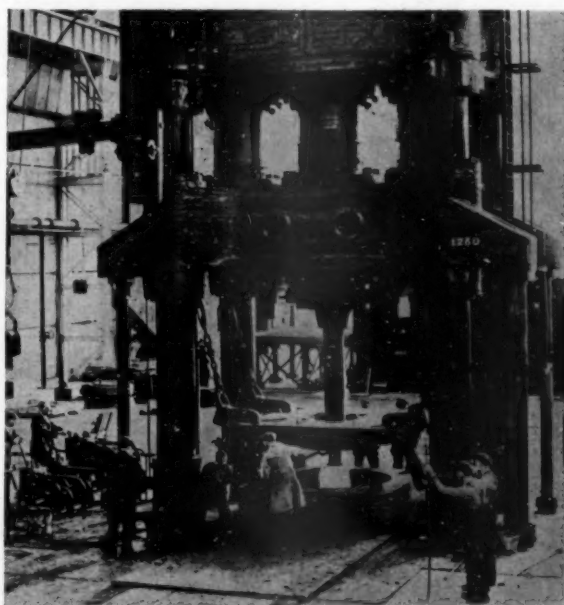


Fig. 1.—Vertical hydraulic piercing press in action.

being pierced, that is, at a high temperature.

HOT WORK

Neglecting for a moment the rare instances when for dimensional or metallurgical reasons the raw steel has to be drilled by machining, this initial business of making the hole is essentially a hot operation, governed metallurgically by considerations similar to those that apply in other forging and rolling industries, but

mechanically quite different. Temperatures vary with the type of steel being handled, but many of these operations commence at somewhere about 1250° C. Now hot work in tube manufacture invariably involves two stages, (i) the initial making of the hole, and (ii) the subsequent elongation of that pierced bloom to the dimensions where its length is many times its diameter. Generally these two stages are carried out in separate

plants but without intermediate reheating, so the separation is only a matter of yards; an exception is extrusion, where the forcing of a mandrel into a billet is followed in a matter of a second or so by the operation of squeezing the billet, still on its mandrel, through an orifice, that is, a die, all in one press; nevertheless, it is a two stage job. Some elongating processes are characteristically associated with particular methods of piercing, of course, but are not always debarred from being associated with others.



Fig. 2.—Horizontal hydraulic "draw" bench showing tube entering dies.



Fig. 3.—Tube being removed after passing through bench shown in Fig. 2.

Piercing

Since the first step is necessarily to make a hole, and not to take a hole and put steel around it, it will be convenient first to review the business of piercing. There are several ways of doing this, broadly falling into two groups according to whether or not the steel revolves on its own axis during piercing. The more simple and earlier established methods do not involve any spinning or rotating, that is the piece of steel of suitable shape is pierced by pushing a bar through it to make the central hole.

Punch Piercing

The billets used are substantially square in cross section, which means pushing them through a continuous furnace with a sloping hearth, turning each billet over in the soaking zone to help ensure uniform heating. Furnaces may use any convenient fuel, such as producer gas (the most common), town's gas, or pulverised coal or pitch. In practice the billets are square with rounded corners, the across corner measurement being such that the hot billet will just slide into the cylindrical matrix of a vertical hydraulic press. A punch is then forced down vertically into the centre of the billet, deforming the square prism shape into the round, and practically filling the matrix. Depending on the relative cross sectional area of the punch, of the annular space between the punch and the matrix, and the original area of the billet, the steel may then be forced upwards around the punch bar by a sort of backward extrusion, an effect which is termed "over filling," but the stroke of the punch is of such a

length that the leading end does not travel right through to the bottom of the matrix. This produces a thick walled thimble or bottle which is held in the matrix by a stripper plate when the punch is withdrawn. The bottle is then pushed up out of the matrix and conveyed, manually or mechanically according to size or weight, to the second stage, that of elongating it to the required diameter and length.

Push Bench

This second operation, carried out generally without reheating, consists in putting the closed-ended bottle on to the leading end of a long bar that can be moved horizontally in such a way as to force the hot hollow bloom through a series of dies of gradually decreasing bore. The apparatus on which this is done is known as a push bench. It is clear that the effect will be to squeeze the tube backwards along the bar as the latter moves forward, the thrust being taken by the periphery of the closed end of the tube, that is, the end that was left on by reason of the fact that the original vertical punch bar did not quite reach the end of the billet in piercing. So in this elongating stage the tube is forced hard down on to the push bench mandrel bar, and its thickness is determined by the annular space between the last die and the mandrel. After the rear open end of the tube is clear of the last die, the ram that pushes the mandrel forward is reversed, leaving the tube with the bar still in it to move forward on live rolls to a reeler, or polishing mill. This is a machine that works on the oblique rolling principle, in which two barrel-shaped rolls set at an appropriate angle

serve to spin the tube and pull it forward at the same time, squeezing the tube between the rolls and the mandrel so that it tends to stretch the still hot steel into an oval with a continuously changing pair of axes, since the tube is spinning. The amount of ovalling, governed by the pressure applied by the oblique rolls, is only just sufficient to loosen the tube from the mandrel. In the next stage the bar is pulled out of the tube by holding a stripper plate behind the open end of the tube. The bar returns to its place in the cycle of many such mandrels used in continuous production, and the tube travels to a hot saw for removing the thick end, which is scrapped. This gives a hot finished tube ready for subsequent operations to be described later.

The push bench process is applicable to tubes between just under 3 in. and rather more than 8 in. outside diameter, and in thicknesses between about $\frac{1}{8}$ in. and somewhat less than 0.1 in. Indeed, tubes as thin as 15 gauge (0.072 in.) have been made, hot finished, by this method, when all conditions have been favourable. The length is obviously limited by the length of the mandrel bar in the horizontal ring bed, as it is called. By using a double ring bed, 4 in. tubes are produced in this country up to 40 ft. long.

The grain flow of the steel is entirely longitudinal, except of course that in punch piercing the centre of the billet is pushed to the bottom of the bottle and to some extent squeezed up the sides. The top of the billet (with its scale, if not removed) becomes the

inside of the bottom of the bottle, and instances have been known in which an identification number stamped on the upper end of the billet is still decipherable at the bottom of the inside of the bottle. The process as described is not very suitable for the manufacture of thick walled tubes of a low diameter/thickness ratio, owing to the risk of some eccentricity and naturally the thicker the tube, the hotter will the bar become. One may, of course, use rolls instead of dies, thus minimising friction and the risk of die scores on the outside of the tube, but introducing some greater problems of maintenance.

similar to the manufacture of non-ferrous tubes, in which a short round billet is inserted in a horizontal cylindrical matrix and a bar is pushed right through its axis to protrude on the far side. The end of the bar is then in a position centrally in the orifice of a die, and the elongating stage follows immediately by the pushing of the pierced billet forward to extrude it through the annular space between the die and the nose of the mandrel that pierced the hole. This process "squirts" a tube through the die over the mandrel in a matter of a couple of seconds, the size of tube being at present anything from about

1½ in. to 4 in. diameter and, say, 9 gauge (0.144 in.) to perhaps ½ in. or ¾ in. thick by some 10 ft. long. Tool wear is a costly item, and restricts extrusion to materials that in themselves are high in initial cost. Such materials, for example stainless steels, are so much less easy to work than more often than not the billets are drilled with a central hole before heating, and the insertion of the mandrel serves merely to expand that drilled hole. The die, a relatively long cone, forms the forward end of the

matrix, and the ram is of similar profile, so that after the tube is extruded it is cut off from the thin conical "umbrella" left behind in the die. Practically all the cold drawn stainless steel tubes made in this country start life as extruded hollows produced in this way on a 1,300 ton hydraulic extrusion press.

Cupping and Drawing

The other non-rotating process is not strictly piercing, for it consists in cupping a flat disc in a succession of dies until the result is a short squat tube with one end closed in the hemispherical form of the nose end of the punch. Thus the process starts with what is really a "dishing" operation into a die of appropriate form, followed by dies of smaller and smaller diameter, both punch and bottle being withdrawn and the die changed after each operation. Eventually the flat disc is virtually hot-deep-pressed into a thimble form squeezed against the mandrel, and is then stripped off. This is slow and laborious and limited to relatively short lengths of a few times the diameter. It is, however, well suited to the production of short squat tubes with one end hemispherically closed. Certain types of gas cylinders are made in this way, the open end being subsequently hammered down to the conventional shape to take a valve. It is not really suitable for the familiar cylinders for permanent gases, or like bottles having a large ratio of length to diameter. The two flat surfaces of the original disc, bottom and top, become respectively the outside and inside surfaces of the

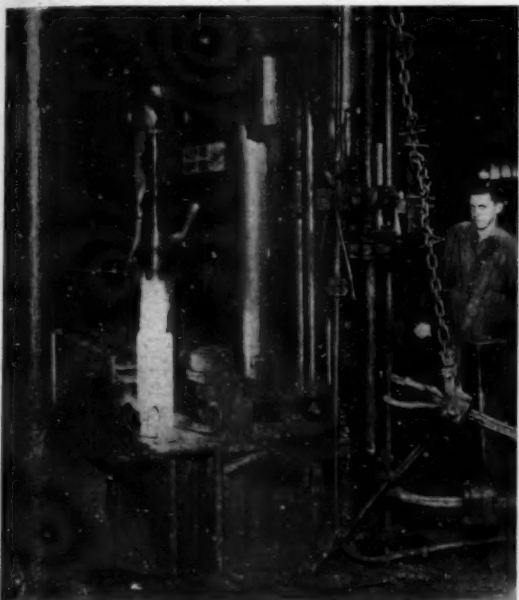


Fig. 4.—Vertical hydraulic piercing press in action using smaller billets than in Fig. 1.

Ehrhardt Process

There are variations on the same theme. An early process still in extensive use was due to the German, Ehrhardt, and employs only a few dies, say, up to 3 or 4, instead of perhaps 20 or 30 dies in the push bench described above. This Ehrhardt process is particularly applicable to large and heavy tubes, even to water drums up to 36 in. diameter. In such cases the billet may be as much as 48 in. across corners and some 20 tons in weight, which introduces handling problems of a special kind and necessitates gagging the tube off the horizontal bar instead of reeling.

Extrusion

There are two other non-rotating processes that deserve honourable mention. One is extrusion, rather

Fig. 5.—"Push bench" showing dies through which the hot punch-pierced bottle is pushed horizontally.



final gas cylinder. In the United States this process is used for greater length/diameter ratios than in Great Britain. The method is just 100 years old, having been first used in this country in 1845.

Rotary Piercing Barrel Mill

In all the processes mentioned so far there is no rotation of the original solid billet on its axis, but rotary

the middle of the driven rolls. Alternatively when the billet travels along or below that imaginary horizontal centre line of the pass, solid guides are used underneath and above.

Now as the billet moves forward it undergoes the characteristic deformation associated with a cross rolling operation between rolls of this shape. It gets increasingly more oval, to use a loose expression, as it approaches

artillery shell, the spinning ovaling billet will pass over it, and the plug serves to ensure that the centre opens out into a round hole more or less concentric with the outside diameter. In this way the hot billet passing over the piercing plug emerges as a rough thick walled pierced bloom. To illustrate relative dimensions, a 4 in. round can be readily pierced over a 2 in. diameter plug, and a 17 in. round

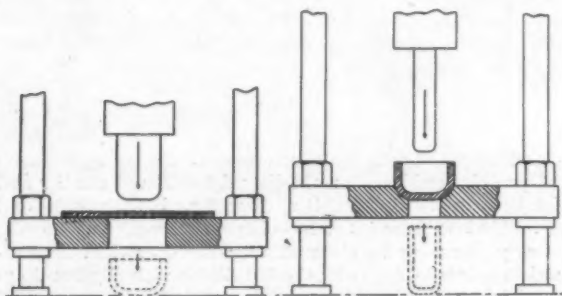


Fig. 6.—Diagram illustrating the cupping and subsequent pressing of a disc to form a hot finished tube.

piercing processes are at one and the same time more extensively used and much more difficult to describe. They need to be seen, almost, to be believed. Imagine two rolls, not of substantially uniform diameter and one above the other, as for instance in sheet rolling, but markedly barrel-shaped and side by side. Not only are they side by side but in the vertical plane their axes make an angle of a few degrees with each other, above and below the horizontal. The diameter of each roll is less at the two ends than in the centre, so the surface speed increases from one end towards the middle and decreases again to the other end, although the angular speed is necessarily constant.

Imagine next that a round billet is pushed endwise into the angle at one end of these two rolls, instead of at 90° to the rolls as in bar rolling; meanwhile the rolls are rotating at a high speed, each on its own axis and both in the same sense, let us say clockwise. As soon as the end of the hot round billet contacts the rolls it is gripped at diametrically opposite points and will spin in an anti-clockwise sense. The effect of the roll shape and of the angle between the rolls is to make that spinning billet travel forwards into the gradually narrowing zone between the rolls. The billet is guided in its progress by a third idler roll of similar shape mounted above the other two when the billet travels above the line joining the centres of

the region of maximum crush. This ovaling occurs as the billet rotates, so that the surface of the billet is stretched in each element of its circumference successively. This stretching weakens the axis of the billet, tending to open it out. In the forging of bars even between practically flat surfaces one can produce central cavities when the bar being forged is rotated. How much more likely this will be therefore when the surface stretching is done between the round surfaces of high

with a 10 in. plug. The outside diameter of the pierced bloom is generally the same as, or slightly larger than, the diameter of the solid billet. The outside surface of the pierced bloom is frequently scored with spiral marks from the piercer rolls, and the bore scored by friction on the internal plug.

On certain sizes it is convenient to allow the plug to rotate as the rolls pull the billet forward over it, thus minimising friction. With a stationary

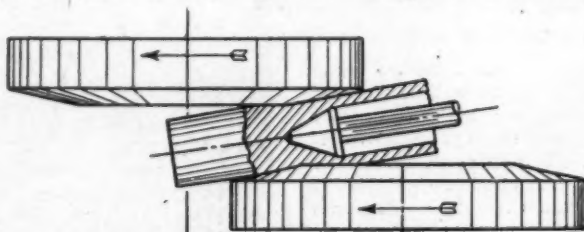


Fig. 8.—Diagram illustrating rotary piercing by the Stiefel method or disc mill.

speed rolls and the peripheral speed of the roll surface in increasing towards this region of maximum crush.

The oblique rolling operation just described, however, does not necessarily leave a hole: it produces central weakness and a tendency to rupture. When ahead of the region of maximum crush a conical plug is held, shaped something like the nose of an

plug, this friction helps to keep the temperature up in the bore; indeed, on a fast operating piercer and using a rimming steel billet (a steel that is not used for rotary piercing now-a-days) the initial temperature has been known to be so high that the friction on the plug has raised the temperature of the bore to the point where the segregate centre has actually melted.

To be continued.

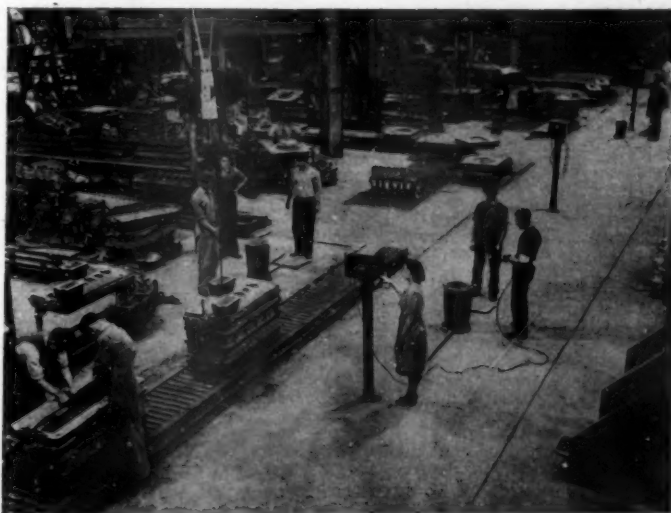
M.A.P. Light Metal Foundries for Peace Production

One of Britain's greatest assets to-day is the potential resources of the light metal industry in meeting civilian needs. Developed beyond all recognition by war-time demands this industry can become a tremendous power in facilitating reconstruction. In this connection the announcement that Renfrew Foundries Ltd. has acquired the light metal foundries at Hillington, Glasgow, formerly operated by Rolls Royce Ltd., for the Ministry of Aircraft Production, is opportune. The flexibility of this foundry, as will be gathered from the following brief outline, will enable it to turn, without re-equipment, to the production of a vast range of badly needed peace-time products.

BRITAIN began the recent war with a diminutive light metals industry. But light alloys of every type are an integral part of aircraft fabrication and it was necessary to increase productivity by long range planning and by the enthusiastic co-operation of management and labour. Many factories were built, equipped and staffed for this purpose. One of the most modern of these factories, and probably the largest of its kind to be erected by the Ministry of Aircraft Production, was that at Hillington, Glasgow, operated by Rolls Royce Ltd. A high proportion of the famous Rolls Royce Merlin engines, which powered the Hurricanes, Spitfires, Mosquitos, Lancasters, Halifaxes, and other R.A.F. aircraft, were produced at this great factory. Production, which commenced in June, 1940, reached a total of 78,952 engine sets by October, 1945; an outstanding example of production engineering in which has been combined, by brilliant planning and high technical skill, not only a high rate of production, but also that standard of quality for which Rolls Royce is justly famed.

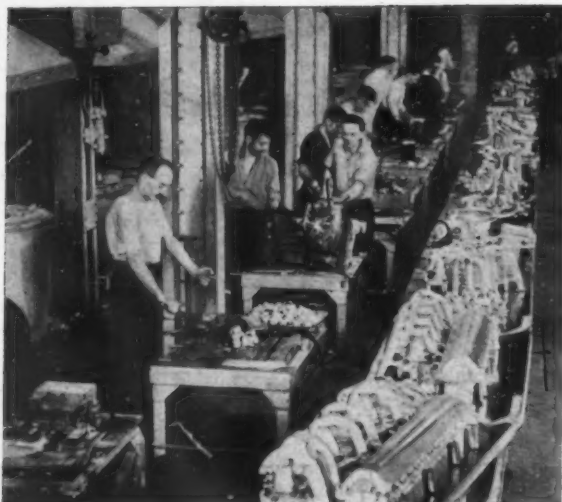
One of the most impressive units of the Hillington factory is the aluminium alloy foundry, which not only has produced all the aluminium alloy castings required for the factory's production, but has supplied them to the other Rolls Royce factories and to the American company which has been making Merlin engines during the war. Some indication of the part played by this foundry is the fact that 31,440 tons of castings were produced between June, 1940, and October, 1945. The peak production of 851 tons was reached in September, 1944, equivalent to a rate of 10,212 tons a year. This is an achievement of a very high order, for in it have been combined the skill and manual dexterity of the moulder, with the vast mechanical devices which are the basis of mass production technique. But there is one important aspect of the high degree of mass production achieved; with it is combined the attainment of the highest quality and precision in the foundry arts and a flexibility which enables changes in design and technique to progress unhindered by the impatient demands of production.

During the war these foundries have employed over 4,000 workers, a high proportion of them women, most of whom had no previous experience of foundry work



General view along one of the bays in the foundry. Note the line of pyrometers mounted along the floor for controlling the casting temperatures.

and have had to be trained to operate the ingenious machines whose superb design alone made possible the production of complicated castings without the moulders' acquired skill. Behind this vast production machine, however, there is the organisation which makes it possible still to ensure quality and flexibility. This consists of the large design department where production equipment and methods are worked out to the finest detail, the lavishly equipped pattern shop and tool room where craftsmen in wood and metal give shape to the designers' drawings with a rapidity previously unapproached in this type of work, and the experimental foundry where the whole production plan for every new design is tried out on a production scale and 100 perfect castings have to be produced before the job is passed on to the main production foundry. There is the laboratory where foundry scientists and their assistants study and control every phase of production, where the sand is tested, the material analysed, the castings tested for strength and hardness and submitted to the searching probe of X-rays. Every mould, every core, and every casting produced is submitted to a careful inspection for dimensional accuracy and soundness and finally the



A general view of the gravity die-casting department, showing operators working from "bale out" type furnaces to the gravity die. A power driven conveyer transports the castings to the department for subsequent operations of sawing, fettling, inspection and heat-treatment.

castings are set up in elaborate jigs for spot facing, so that they will fit directly in the jigs in the machines in the aero-engine factory without any need for further inspection or adjustment.

This, then, is a brief outline of the Hillington light alloy foundry. It has finished the important war job it was built to perform. It has come through with credit and a certain fame but it still remains a great productive unit, the most modern of its kind this country possesses and believed to be the largest and best equipped light alloy foundry in Europe.

Although Britain began the war with a diminutive light metals industry, to-day, having achieved victory, she can count among her greatest assets the thriving new industry of tremendous potential power for civilian needs. The flexibility of the Hillington light alloy foundry will enable it to turn, without re-equipment, to the production of a vast range of badly needed peace-time pro-

A section showing the operation of "Jig and Spot Location" of castings. This method eliminates the "marking out" of castings in the machine shop.



General view of final dimensional inspection. Checked castings are placed in perforated containers and transferred to heat-treatment furnaces.

ducts. Already the conveyers in this unit are carrying many civilian products interspersed between aero-engine castings, indicating that there need be no time lag during the change-over from war to civilian production.

Determined that this great production asset will play a key role in the great task of reconstruction and re-equipment which lies ahead, Colonel W. C. Devereux and his associates have combined with Rolls Royce Ltd. to form a new company, Renfrew Foundries, Ltd., which will take over the Hillington foundry, keeping it in production in peace time and maintaining in employment those who have made so magnificent a contribution to the war effort.

In future "Renfrew" castings will be found in peace-time guise in saucepans, kettles, cooking ranges, flat irons, furniture, household fittings and fixtures, motor vehicles, railway rolling stock, aeroplanes, aero engines, ships, and a thousand and one pieces of machinery and equipment which British industry will produce now that the war is over. Nor will the urgent needs of the export trade be forgotten. The foundry is in a most favourable position to supply the needs of many countries and it can certainly compete with the best that can be obtained from elsewhere.

To the proved resources of the foundry there is now added, as a result of its association with Colonel Devereux's organisation, the assurance of plentiful supplies of raw material of the highest quality and the support of the excellent facilities existing for scientific research and development, teams of engineers and designers of the very highest calibre and powerful marketing forces.

The accompanying illustrations show a few sections of this foundry unit taken over by Renfrew Foundries Ltd., which now offer to all branches of industry the largest and most up-to-date plant and equipment for the production of light castings; unparalleled facilities for pattern making, die design, die sinking and other features which contribute to the attainment of most rapid development from drawing to prototype castings; high quality and accuracy in castings; unique facilities for scientific research and development on all questions of materials, processes and products; and experienced advice and assistance on all questions concerned with the use of light alloy castings and the exploitation of the advantages they offer.

Residual Elements and Gas Contents of Cast Iron

By J. E. Hurst, D.Met.

In his recent Presidential Address to the Staffordshire Iron and Steel Institute, Dr. Hurst discussed the above subject in such a manner as to form a continuation of his previous address to the Institute. In the earlier discussion he considered the foundry problem of variation in character and/or quality of castings produced from apparently the same materials. He gave details of a case of continuous production of a certain type of casting in which, although the chemical composition as normally assessed showed no significant differences, epidemics of porosity on hydraulic tests at irregular intervals caused considerable trouble. Observation appeared to connect these epidemics with the characteristics of the pig iron in the metal mixture, and investigation revealed a definite difference in microstructure between the sound and unsound types, which appeared to correspond to a difference in the structural character of some of the pig iron in the metal mixture. In this case he was able to show a difference in hydrogen content in both the pig iron and the castings.

Search for improved understanding of this foundry problem directed attention to the presence or absence of elements or constituents present in the cast iron, other than those normally relied upon for control of the composition. Dr. Hurst classifies these as residual elements and gas contents, his address on the subject is presented in this article.

The Effect of Residual or Trace Elements

IT is well understood that small changes in chemical composition can be accompanied by very substantial changes in the characteristics of cast iron. It may be of interest to recall one or two examples of the profound influence exerted by comparatively small additions, almost traces of elements not normally considered in the routine control of the composition of iron for castings. One example can be drawn from the influence of aluminium. An addition of this element in proportions of the order of 0.10% or less under certain circumstances has a profound effect, causing an iron which might otherwise have a hard white or mottled fracture to solidify grey. The reverse effect results from the addition of small traces of the elements boron and tellurium. The example illustrated by Figs. 1 and 2, shows very clearly the influence of an addition of 0.10% of tellurium to an iron which, without tellurium, solidifies completely grey as in Fig. 1. The mere addition of such a small quantity of this element has brought about the complete whitening of the structure as shown in Fig. 2.

Additional examples could be provided, but perhaps this one will suffice to illustrate the importance to be attached to the influence of residual elements. The view can be taken that this is a matter of increasing importance, for with the large amounts of scrap and secondary materials made available by the war, many of which contain deliberate additions of some of these rarer elements, e.g., boron steels, the risk of contamination in our various cast irons has increased greatly.

Service Behaviour of Cast Irons

We must all be agreed that the chemical composition of cast iron as normally assessed is insufficient in itself to enable the prediction of its behaviour in service, and I have no doubt that many, from their own experience, could quote examples where, in spite of the normal composition being identical, unexpected differences in service behaviour have arisen. The example referred to previously when I gave details of epidemics of porosity in the continuous production of a particular type of casting, which caused considerable trouble, is a case in point but, in order to build up my case, I wish to quote some further examples of a different type.

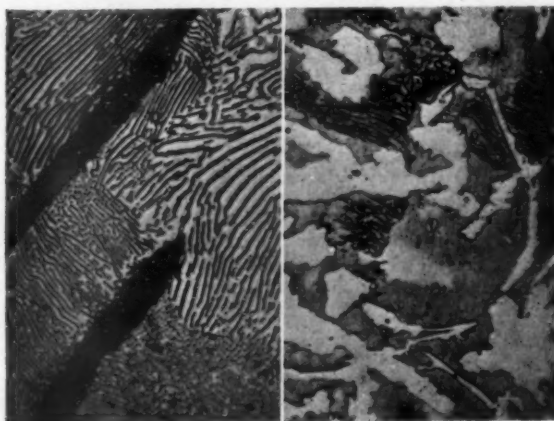


Fig. 1.—Grey iron without tellurium addition. $\times 600$.
Fig. 2.—Same iron as Fig. 1, but with 0.10% tellurium. $\times 600$.

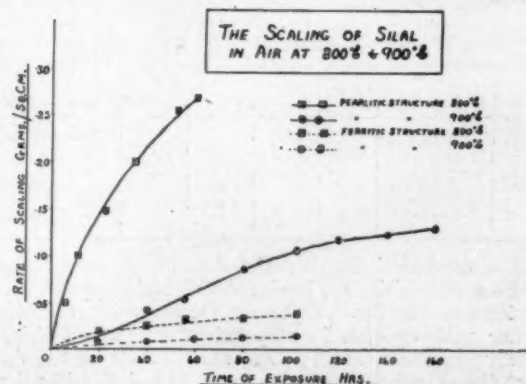


Fig. 3.—Rate of scaling of Silal with different structures.

The high silicon heat-resisting cast iron, Silal, developed by the British Cast Iron Research Association and containing approximately 6% of silicon, provides an excellent example of the type of case I have in mind.

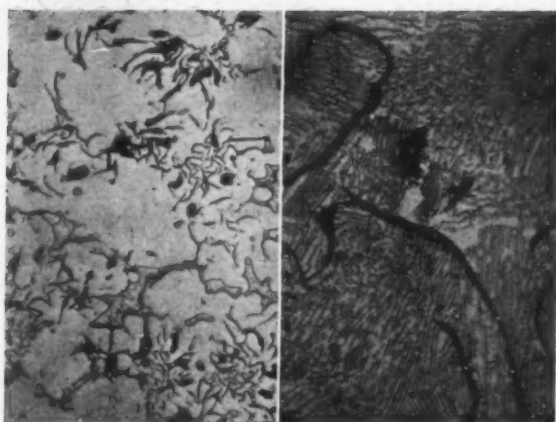


Fig. 4.—Good Sialal structure. $\times 120$. Fig. 5.—Bad Sialal structure. $\times 600$.

In Fig. 3 the rate of scaling or oxidation is shown of two samples of approximately similar composition as normally assessed. In spite of the close similarity of composition the rate of scaling in one is vastly greater than the other. The best sample has a microstructure as in Fig. 4, consisting of fine graphite dispersed in a completely ferritic matrix quite different from the poor sample which, as shown in Fig. 5, has a coarse graphite structure and a matrix not wholly ferritic but containing some pearlite. In our normal method of manufacturing this alloy, in a direct arc furnace, we secure the correct structure for maximum scale resistance, that is, the fine graphite ferrite structure. But we do encounter strange variations in structure which can be classified in three types, viz.: (1) Ferrite-fine graphite, (2) Coarse graphite-pearlite, and (3) Coarse graphite, pearlite and carbide or silicide. The results in Table I show a collection of routine analyses of a number of casts in which each of these three types of structures have been observed, and it will be clear that as far as they go these show nothing to indicate the cause of the structural differences recorded. I must add that in every case the analyses and structural examination have been carried out on identically shaped specimens, viz., the test bars from the furnace heats.

TABLE I.—SIALAL. TYPICAL COMPOSITIONS AND STRUCTURES.

Carbon	Silicon	Sulphur	Phosphorus	Manganese	Nickel	Chromium	Copper	Type
2.09	5.40	0.064	0.27	0.49	0.34	0.12	0.14	Good I
2.14	5.11	0.070	0.26	0.48	0.20	0.06	0.13	Good I
2.20	5.76	0.060	0.22	0.46	—	—	—	Bad II
1.98	5.64	0.066	0.23	0.60	—	—	—	Bad II
2.28	5.57	0.070	0.21	0.53	—	—	—	Bad II
2.12	5.66	0.046	0.25	0.40	0.18	0.08	0.10	Bad III
2.24	5.52	0.056	0.22	0.65	—	—	—	Bad III

A somewhat similar experience has been encountered with an austenitic cast iron of the Ni-resist type as used in the manufacture of pumps, for pumping chemical liquor with crystals in suspension. These conditions involve corrosion and erosion, and in spite of the fact that the chemical compositions are practically identical as normally ascertained the castings with the structure shown in Fig. 6, possessing coarse graphite, are completely unsatisfactory in behaviour when compared with the alloy having the fine graphite structure illustrated in Fig. 7.

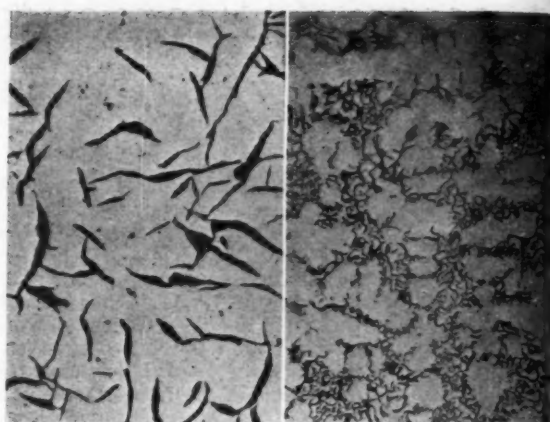


Fig. 6.—Bad Ni-resist structure. $\times 200$.

Fig. 7.—Good Ni-resist structure. $\times 200$.

These examples demonstrate that cast irons similar in chemical analysis, so far as we normally take the analysis, can show profound differences in service behaviour and in structural character. With the knowledge that the structural character can be modified very considerably by the presence of residual or trace elements it will be clear that the understanding of such differences in behaviour or structure can never be complete without knowledge of the nature, character and amounts of such extraneous elements present. Even if it were possible no attempt is made here to provide an explanation of the differences in behaviour recorded, nor must it be assumed that in these cases the differences are due to residual elements and dissolved gases, our information and data is not yet sufficient to say either one way or the other. The facilities at the disposal of the metallurgical laboratory to-day do ease the burden substantially in endeavouring to obtain full and accurate appreciation of the composition in such cases.

TABLE II.—COMPOSITION OF BRITISH AND AMERICAN CYLINDER IRONS.

	British	America
Carbon	3.36%	3.37%
Silicon	2.08%	2.13%
Sulphur	0.105%	0.116%
Phosphorus	0.14%	0.19%
Manganese	0.89%	0.77%
Nickel	0.115%	0.115%
Chromium	0.36%	0.34%
Molybdenum	0.03%	0.03%
Tungsten	absent	absent
Vanadium	0.03%	0.03%
Titanium	0.02%	0.02%
Cobalt	slight trace	slight trace
Copper	0.130%	0.115%
Aluminium	0.05%	0.05%
Zirconium	absent	absent
Tin	"	"
Lead	"	"
GASES:		
Oxygen	0.0062%	0.0065%
Hydrogen	3.3 mls. per 100 grms. metal	7.8 mls. per 100 grms. metal
Nitrogen	0.0065%	0.0055%

For example, I can quote the results of an examination in my laboratory of two cylinder castings, one of British and the other of American origin. The normal analyses of these castings showed them to be very similar. The two castings examined were almost exactly similar in this respect. Experience showed marked differences in machinability, and it was alleged that the behaviour in service from the point of view of wear



Fig. 8.—Typical U.S.A. cylinder iron. $\times 120$.



Fig. 9.—Typical British cylinder iron. $\times 120$.

resistance likewise differed. The micro-photographs, Figs. 8 and 9, show the American casting to contain a larger proportion of ferrite. The chemical compositions determined by chemical and spectrographic analysis are recorded in Table II and significant percentages of additional elements are revealed. What might be quite an important difference revealed by these analyses is in the titanium content, which in the British is substantially higher than in the American casting. The results of the determination of the oxygen, nitrogen and hydrogen contents by the vacuum fusion method are recorded also in Table III.

TABLE III.—COMPLETE ANALYSIS OF THE TWO SAMPLES OF MALLEABLE IRON.

	SAMPLE A. Dull Black Desirable Fracture.	SAMPLE B. Bright Crystalline Fracture.
Total Carbon	0.93%	0.89%
Silicon	0.38%	0.40%
Sulphur	0.100%	0.110%
Phosphorus	0.086%	0.086%
Manganese	0.31%	0.36%
Nickel	0.01%	0.01%
Chromium	0.02%	0.02%
Molybdenum	0.01%	0.01%
Vanadium	0.01%	0.01%
Titanium	0.04%	0.02%
Copper	0.02%	0.02%
Aluminium	0.04%	0.10%
Tellurium	Nil	Nil
Boron	Nil	Nil
Calcium	0.005%	0.006%
Other Metals	absent	absent
GASES.		
Oxygen	0.0050%	0.0062%
Nitrogen	0.0070%	0.0105%
Hydrogen	2.08 mls. per 100 grms.	2.26 mls. per 100 grms.

The content of oxygen and nitrogen is very similar in both castings, but in the case of the hydrogen the content of the American casting is over twice that of the British.

A further example involves the results of the examination of two samples of blackheart malleable castings. One of these revealed a dull black fracture, and had a microstructure as shown in Fig. 10. The other, with a microstructure illustrated in Fig. 11 had a bright crystalline fracture. The chemical composition determined both chemically and spectrographically, together with the vacuum fusion results for oxygen, nitrogen and hydrogen are given in Table III.

In connection with boron and tellurium contents, which we have returned as nil, it should be mentioned that in this case, it means that under our conditions of

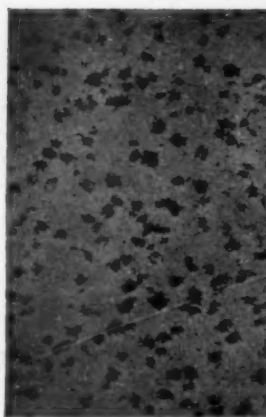


Fig. 10.—Good blackheart malleable having dull fracture. $\times 22$.

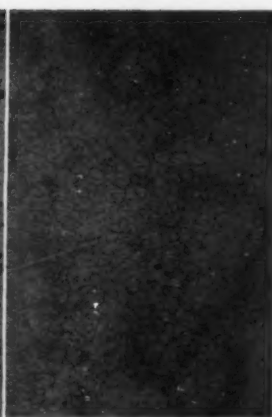


Fig. 11.—Poor quality blackheart malleable having bright crystalline fracture. $\times 22$.

excitation no trace of any boron lines occurred. As yet we are not able to say that under any other conditions of excitation traces would not be found. Also, although we have found calcium our experience leads us to believe that this is not in the alloy, but arises from calcium present in the apparatus.

The normally determined compositions of these two samples are for all practical purposes identical. Significant amounts of other elements were found to be present, and important differences were found only with the titanium, aluminium and nitrogen, the iron having the dull black fracture being the lower in aluminium and nitrogen and higher in titanium. The hydrogen content showed little difference.

The analyses of two large marine diesel engines cylinders (A) and (B) set out in Table IV are included as an example of a deliberate attempt to duplicate a composition containing very small amounts of additional elements. Cylinder (A) represents the pre-war quality, the composition of which has been duplicated in cylinder (B). The structural character of the two cylinders is illustrated in the micrographs, Figs. 12 and 13, showing the etched structure of (A) at magnifications of 120 and 600 respectively, and Figs. 14 and 15 the corresponding structures of cylinder (B).

I cannot offer an explanation of the differences in behaviour recorded in these various examples. They do show that with the resources at our disposal to-day

TABLE IV.—CHEMICAL COMPOSITION OF THE IRONS.

	SAMPLE A. Tensile Test Piece.	SAMPLE B. Piece of Casting.
Total Carbon	2.94	2.92
Graphitic Carbon	2.22	1.85
Combined Carbon	0.72	1.07
Silicon	0.71	0.97
Sulphur	0.096	0.065
Phosphorus	0.37	0.47
Manganese	0.95	0.79
Nickel	0.06	0.17
Copper	trace	trace
Chromium	0.09	0.12
Molybdenum	trace	trace
Titanium	0.08	0.05
Vanadium	0.16	0.17

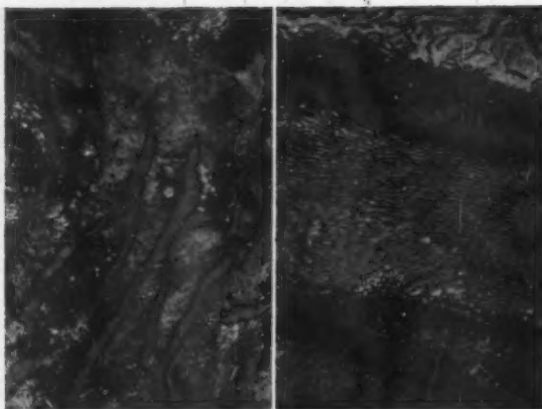


Fig. 12.— × 120. Fig. 13.— × 600.
Pre-war quality marine Diesel engine cylinder.

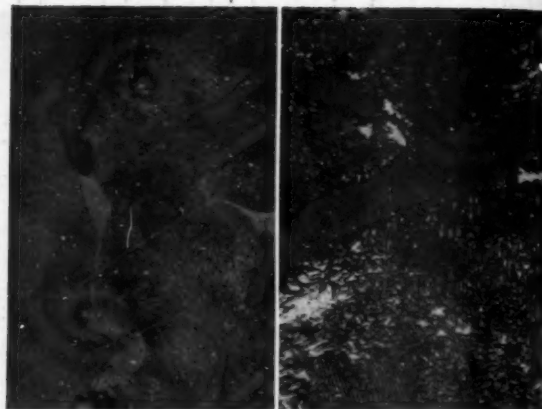


Fig. 14.— × 120. Fig. 15.— × 600.
Substitute marine Diesel engine cylinder.

we are able to explore more fully the composition of cast iron and, with some facility obtain reliable information as to the nature and amount of residual or trace elements and gases present. It will be obvious that it is necessary to accumulate much more data on which to build up an understanding of these incidents, but it will be equally obvious that, in a case like the British and American cylinder castings, no explanation of the difference in behaviour that does not take into account the difference in titanium and hydrogen content can be completely satisfactory. To those who might expect the ubiquitous hydrogen to provide an explanation for all these difficulties the example of the two malleable castings will serve to keep their feet on the ground. It is worth mentioning that the hydrogen figures reported are the values for residual hydrogen in the specimens at the time they were examined. What relation this value has to the hydrogen content of the molten metal or at the time of solidification, if any, is not known. These are amongst the various aspects of this matter of residual elements and gas contents we are pursuing in our laboratories at present.

Soundness in Castings

Perhaps an example of experimental work in this field more closely related to production might prove specially interesting to those who view the previous work described as somewhat remote. An example of this type concerns the production of castings in high silicon acid-resisting iron. During the early part of May this year an abnormally high incidence of subcutaneous pinholing in castings occurred. In the investigation of this gas analyses were taken from the routine test samples representing the casts affected. These samples are in the form of $\frac{1}{2}$ in. diameter bars cast in dry sand moulds. The results of these analyses in four individual cases are recorded in Table V. In the earlier discussion to which I have referred I was able to state that the greatest single trouble in the production of sound castings arises from the gas content, principally hydrogen, and that if this gas is in excess of 2 mls. per 100 grms. unsoundness invariably occurs. It will be observed that in all the cases examined the hydrogen content is well above this limiting figure. The remelted ingots during this period showed an equally high hydrogen content of 2.8 to 3.0 mls. per 100 grams.

	(1)	(2)	(3)	(4)
Oxygen %	0.0022	0.0018	0.0025	0.0015
Nitrogen %	0.0026	0.0023	0.0014	0.0023
Hydrogen mls. per 100 grms.	2.70	2.35	2.95	2.55

	Annealed Ingot.	Casting Heat.
Oxygen %	0.0030	0.0059
Nitrogen %	0.0016	0.0029
Hydrogen mls. per 100 grms.	1.85	1.40

	(1)	(2)	(3)	(4)
Oxygen %	0.0030	0.0030	0.0016	0.0004
Nitrogen %	0.0029	0.0036	0.0024	0.0049
Hydrogen mls. per 100 grms.	1.40	1.34	2.32	1.44

It was, therefore, decided to submit the remelted ingots to annealing treatment to reduce the hydrogen content. The results obtained after this treatment are shown in the table and show a reduction in hydrogen to 1.85 mls. per 100 grams, and a completely satisfactory casting heat utilising this annealed ingot, having a hydrogen content of 1.40 mls. per 100 grams. To complete the story a few random samples from casts during July are included and show with one exception the hydrogen content below the critical value, and complete freedom from troubles due to unsoundness in the form of pinholes and blowholes.

This example demonstrates the real importance and value of work and development in this field of residual elements and dissolved gases. But in dealing with the subject matter as indicated by the title I am conscious that many questions remain unanswered. This is inevitable in the present state of our knowledge. If, however, it succeeds in stimulating further investigation the difficulties encountered in the production of sound castings, capable of giving good service, the results may lead to greater simplification.

An Electronic Material Analytical Comparator

In connection with our reference to the above instrument on page 256, October issue, the correct registered address was given of the firm marketing the instrument, but we have been asked to advise interested readers to contact Stuart Davis Ltd., 14, The Butts, Coventry, for any further information they desire on the instrument.

Absorptiometric Methods of Analysis for 18/8 and Similar Steels

Determination of Chromium, Nickel, Manganese and Molybdenum on one Sample Weight

By B. Rogers

Chemical Laboratory, Murex Welding Processes Ltd.

Using the Hilger Spekker Photoelectric Absorptiometer, Vaughan's¹ work has been adapted in the direction of routine methods for the determination of chromium, nickel, manganese and molybdenum on one sample weight, for the 18/8 and similar steels included in the specification: 12-25% chromium; 6-14% nickel; 0.7-4.0% molybdenum; and 0.3-2.0% manganese. Compared to the routine chemical methods, there is almost an equal accuracy, slightly inferior for chromium, whilst the speed of the methods is nearly doubled when seven samples are analysed together.

IN 1943, Vaughan's work was noted and attempts made to apply similar principles to the analyses of the variety of steels coming into the routine chemical laboratory containing anything from:— 12-25% chromium; 6-14% nickel; 0.7-4.0% molybdenum; and 0.3-2.0% manganese.

The tungsten lamp was the illuminant used at first, with Ilford filters. Later on, a mercury vapour lamp was used with better results on some of the determinations but not on others. Finally the tungsten lamp procedure was put into routine use and has served well for two years for the analyses of 18/8 steels, stainless irons and steels and weld metal deposits of a similar specification. There is still scope for the scheme to be extended, by those interested, to include the determinations of tungsten, titanium and vanadium, whilst the analyses of columbium steels by these methods is under consideration.

The usual considerations relevant to Vaughan's work¹ on the determinations of the four elements chromium, nickel, manganese and molybdenum, were again applied, with modifications, particularly as regards the last mentioned element. A knowledge of this work is assumed.

Synthetic steel solutions made from pure potassium dichromate, potassium permanganate, flake nickel and sodium molybdate were prepared for 18/8, 4 (Mo), 1 (Mn) steels and the results were confirmed by the analyses of standard steel. Graphs were prepared by following the method.

Reagents and Solutions Required

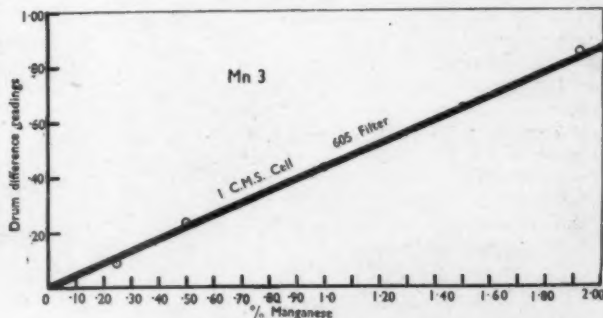
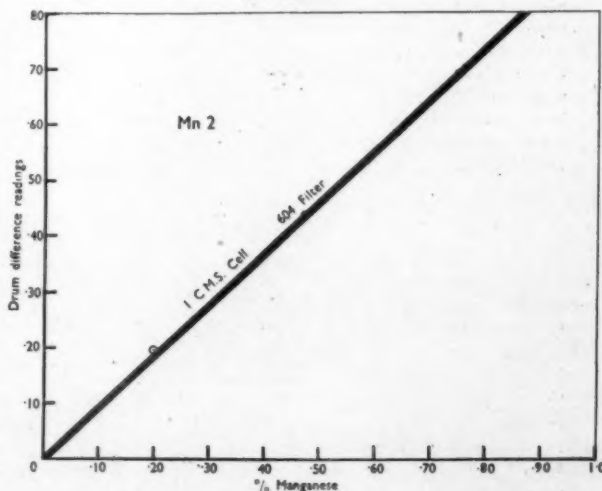
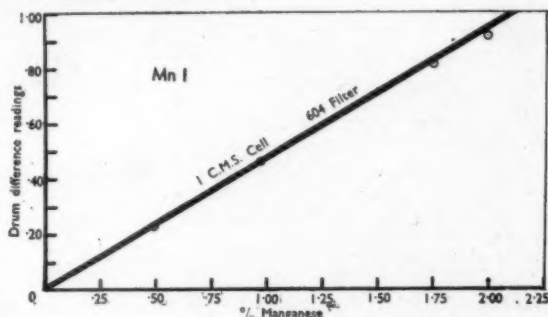
The following acid mixture dissolves the 18/8 steels more speedily than ordinary Spekker acid:—

Conc. Spekker Acid :—150 mls. of conc. phosphoric acid
150 " " " sulphuric acid
This mixture is cooled and diluted to a volume of 650 mls. with distilled water.

For Chromium and Manganese determinations:

1. A 2% solution of silver nitrate (AR).
2. Analoid Amm. persulphate tablets (each of 2.5 grams weight).
3. Urea tablets (each of 0.5 grams weight).
4. AR pot. permanganate and AR pot. dichromate crystals.

¹ E. J. Vaughan, "The Use of the Spekker Photoelectric Absorptiometer in Metallurgical Analysis." Monograph published by Royal Inst. Chemistry.



5. Spectroscopic iron. Dissolve in dil. nitric, and/or sulphuric acids.

6. A 2% solution of sodium nitrite (AR).

For Nickel determinations:

1. *Spekker Acid*. Diluted to 1% of its original strength.

2. *Amm. Citrate Solution*. 500 grams of AR citric acid crystals are placed in a 1000 mls. beaker. Approximately 100 mls. of water are added, and the solution is warmed and stirred for 5 mins., then cooled. Some crystals may be held back and added during the process of gradually neutralising the acid with 500 mls. of ammonia. A sink in the fume cupboard is useful for this operation.

3. *N/10 Iodine Solution*. 12 grams of iodine (AR) are mixed with 20 grams of potassium iodide (AR) and approximately 40 mls. of water, shaken, and when dissolved, diluted to 1000 mls. final volume.

4. *Amm. Glyoxime Solution*. Add 200 mls. of 50% ammonia (AR) to 1 gram of (AR) dimethylglyoxime reagent and stir until dissolved. Make up to one litre with a 50% solution of ammonia.

5. *Flake Nickel (or Carbonyl Nickel)* standardised by chemical methods).

For Molybdenum determinations:

A.R. reagents are essential.

1. A 50% sulphuric acid solution.

2. A 5% pot. thiocyanate solution.

3. 934 grams of stannous chloride are dissolved in 2.5 mls. of concentrated hydrochloric acid in a 50 ml. covered beaker, heating moderately. An equal volume of hot water is added and the solution is diluted to a final volume of 250 mls. with cold water.

4. Sodium molybdate or molybdic oxide.

5. Spectroscopic iron dissolved in dilute sulphuric acid.

Filters required:—

Ilford, spectrum—

green 604 for the tungsten lamp procedures*

violet 601 " " " " "

blue 602 " " " " "

* Also yellow or green 605 for the mercury lamp procedures.

Procedure

The composite scheme for the determination of chromium, nickel, manganese and molybdenum in 18/8/4 (Mo) steels.

(a) The Tungsten Lamp with Ilford Filters.

Weigh 0.6 grams of the sample into a 500 mls. wide mouthed conical flask. Add 65 mls. of the Spekker Acid made up as described above. This will cut down by about 45 mins. the time required to dissolve the sample if the ordinary Spekker Acid (Vaughan¹) is used. Heat is applied and in the case of some alloys of the type represented by the upper limits of the range i.e., 23% Cr, 4% Mo, etc., keep the acid solution at the original volume, until solution of the steel is obtained. Most 18/8 steels may be allowed to evaporate simultaneously with the acid attack on the steel. Oxidise the solution of the

steel with 5 mls. of conc. nitric acid. Evaporate the solution by simmering until light fumes of sulphuric anhydride have been apparent for two minutes. Cool slightly. Add about 100 mls. of tepid distilled water, and heat until there is no doubt that the sulphate salts are redissolved. Any cloudiness due to about 0.25% silicon or over being present in the steel, should be removed by filtering the solution through a sintered glass disc using suction. The cold solution is made up to 250 mls. volume in a graduated flask.

Fractions are then taken for the individual determinations as below:—

NOTE:—The lamp requires a period of five minutes "warming up" before use.

MANGANESE DETERMINATION

(a) Insert a 50 mls. fraction into a 300 mls. wide mouthed conical beaker. Add 10 mls. of silver nitrate solution. Heat to the boiling point. Add one tablet of Analoid Amm. Persulphate. Boil gently for 2-3 mins. Cool. Add one Urea Analoid tablet. Transfer to a 100 mls. flask. Dilute to the mark with cold distilled water and mix well. Obtain the colour reading using a water to water setting of 1.00 and 2 cms. cells for 0.75% Mn (Max) or 1 cm. cells for 2.0% Mn (max), with spectrum green, 604 filters.

(b) Empty the cell. Add one drop of sod. nitrite solution. Refill the cell with the oxidised solution. Allow to stand for one minute. Under the same conditions as in (a) above obtain the blank reading.

(c) Read off the appropriate graph (Mn I or Mn II) the percentage of manganese corresponding to the difference reading obtained from (a) and (b) above.

CHROMIUM DETERMINATION

Cr. Colour.

(On the fraction taken for the manganese determination).

(a) Read off the drum reading with violet 601 filters and w/w 1.0 setting, and 1 cm. cells on the same or another portion of the solution treated as for Mn blank operation.

(c) Read off the appropriate graph Cr I, the percentage of chromium corresponding to the difference reading obtained from (a) and (b) above.

Cr. Blank.

(b) Dilute a 50 mls. fraction to 100 mls. mark in a graduated flask. Obtain the drum reading directly with violet 601 filters and w/w 1.0 setting, and 1 cm. cells.

NICKEL DETERMINATION

(a) Insert a 5 mls. fraction into a 100 mls. graduated flask. Add 30 mls. of 1% Spekker Acid solution. Add 10 mls. of Amm. Citrate solution. Add 5 mls. of Iodine solution. Add 20 mls. of Amm. Glyoxime Soln. Dilute to the mark. Obtain the colour reading using 1 cm. cells, with spectrum blue 602 filters, and a water setting of 1.00.

(b) To obtain a blank reading, substitute 20 mls. of 50% ammonia solution for the dimethylglyoxime solution and use the same cells, etc. as above. Usually, the blank reading is 0.985.

(c) Read off the appropriate graph Ni I the percentage of nickel corresponding to the difference reading obtained from (a) and (b) above.

MOLYBDENUM DETERMINATION

(a) Insert a 10 mls. fraction into a 50 mls. or 100 mls. graduated flask. Add 10 mls. of 40% sulphuric acid. Add 10 mls. of pot. thiocyanate solution. Add 10 mls. of stannous chloride solution. Allow to stand for 15 mins. Obtain the colour reading, using 1 cm. cells for 2-4% Mo steels and 2 cms. cells for 0.5-2% Mo steels, with spectrum green 604 filters and a water setting of 1.00.

(b) To obtain the blank reading (usually 0.99), substitute 10 mls. of water for the addition of the thiocyanate solution.

(c) Read off the appropriate graph (Mo I or Mo II) the percentage of molybdenum corresponding to the difference reading obtained from (a) and (b) above.

(b) The Mercury Lamp with Ilford Filters.

Warm up for 15 minutes and follow the above method exactly except as regards the following differences:—

MANGANESE DETERMINATIONS

(a) Use the y-green 605, filters and appropriate manganese graph (Mn. 3).

CHROMIUM DETERMINATIONS

(b) Use the Cr II graph.

NICKEL DETERMINATIONS

Take a 5 mls. fraction. (Blank readings are usually 0.98). Use the y-green 605 filter, and Graph Ni II.

MOLYBDENUM DETERMINATIONS

Use 605 filters, and 2 cms. cells for 0.5-2% Mo steel. This blank reading is usually 0.98 (Graph Mo III).

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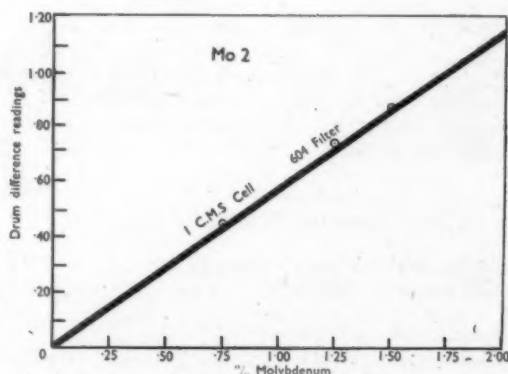
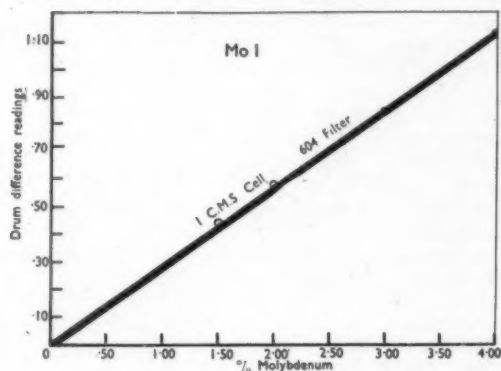
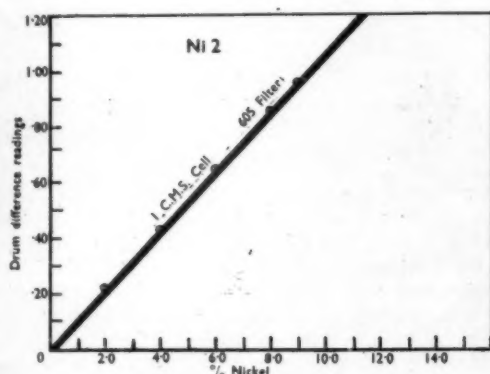
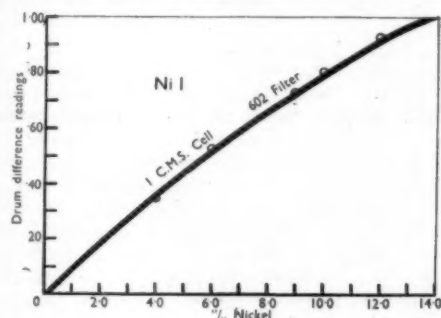
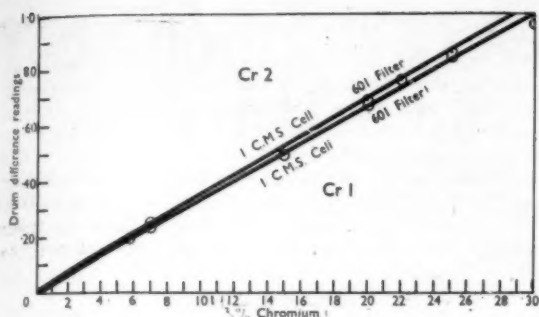
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chemical figures obtained from the dimethylglyoxime method.

5. The manganese determinations agreed within 2% of the three chemical results obtained from the zinc oxide, iron and chromium separation combined with the bismuthate process.

The Speed of the Methods

Seven samples were jointly analysed for four elements in half the time occupied by the above-mentioned reliable chemical methods.

The Accuracy and Precision of the Methods

1. The methods, on twelve tests, indicated standard deviations of $\pm 0.25\%$ chromium, $\pm 0.10\%$ nickel and $\pm 0.013\%$ manganese.

2. Seventeen molybdenum tests deviated from the routine chemical method by an average of $\pm 2\%$ of the molybdenum content of the steel. The chemical method used was the well-tried method involving a soda separation of the iron and chromium: the lead molybdate precipitate was ignited at 600°C . Five tests on one sample gave molybdenum figures of 4.60%, 4.53%, 4.60%, 4.62% and 4.60% on separate beads of the same pad of weld metal and the method is found to be reproducible in routine.

3. The permanganate method for chromium yielded:—18.3% Cr (18.27 to 18.45) on 5 tests against 18.2% Cr. on 12 Spekker tests, but the chemical method does not show so much standard deviation ($\pm 0.1\%$ Cr.) as the Spekker method ($\pm 0.25\%$ Cr.).

4. The figures for nickel obtained from groups of 3, 4, 8 and 12 tests deviate only 1%–2% from the

General Notes

1. A room shaded from strong light is essential whilst vibration is also to be avoided. The results obtained may be periodically checked by analysing a standard steel by the same procedure.

When readings diverging from the average are obtained, such as 0.96 from a chromium blank drum reading for an 18% chromium steel, degrease the cells with chromic-sulphuric acid mixture and follow this by cold water washing.

If this is not done, bubbles of nitrogen will adhere to greasy cell surfaces yielding, usually, higher drum readings which are inaccurate for solutions of 18% chromium steels prepared for determination.

Pure solution readings made as in preparing the graph, when well corroborated, are a reliable guide to average figures for steel solutions.

2. "Blank" operations for chromium and manganese determinations are essential, especially if the silicon content of the steel varies. The chromium blank absorption was shown to be due to chromium mainly,

nickel being responsible for an absorption blank only of 0.01 in 0.09.

3. Blank operations for nickel and molybdenum determinations are not necessary. Originally, great care is necessary in doing molybdenum blanks and once initially determined the results may be accepted, as there is much time saved thereby.

4. It is necessary to fume gently only for the molybdenum determinations, in order to drive off all nitric acid, and no more hydrochloric acid should be present than that contained in the stannous chloride solution. Fading tests were made on a 3.5% Mo steel using the stannous chloride solution used by Vaughan and that same solution diluted to twice its volume. The results indicated that, under the particular conditions of the above method (where only one-fourth the concentration of iron is present compared to Vaughan's method for the alloy steels) the improvement in the stability of the colour using the more dilute solution was marked. Test solutions give the same readings up to 1 hour's time of standing. It is still usual to read directly after 15 mins. as in the original preparation of the graph but there is a nice safety margin of time (up to 30 mins.) should the operator be unavoidably prevented from quickly completing the determinations. Perchloric acid² may be advantageous in the presence of increased hydrochloric acid concentrations, but is not essential in this method. AR. stannous chloride, AR. sodium molybdate and AR. pot. thiocyanate are definitely recommended as being trouble free reagents. Any hydrolysis of the tin salts apparent upon the addition of the stannous chloride solution is easily remedied by agitating the flask con-

taining the molybdenum colour solution for a few seconds.

The stannous chloride solution keeps fairly well. It is not usually necessary to make a fresh solution each day, but it is necessary to have a clear solution. Clean out all cells and flasks, as soon as this is practicable, with warm concentrated hydrochloric acid.

5. Good advice regarding the instrument has now been published by Dr. Haywood² and should be noted. It has been observed by the writer that irregular readings have just preceded the time when the lamp became defunct.

Conclusions

1. There is scope for these methods to be used in all laboratories except those demanding the highest accuracy at the expense of speed.

2. The methods are capable of precise, accurate, and speedy results in the hands of careful operators, provided proper attention is given to the maintenance of the cells and filters in a serviceable condition, and to the use of periodic tests using either synthetic steel solutions or standard steels with the procedure as a safeguard against irregularities.

3. The methods are similar to the chemical methods in accuracy but the nickel chemical method is not regarded as being a routine method in other laboratories.

4. Being based upon pure solutions, the graphs and analyses are independent of classical chemical methods and this consideration is of value to metallurgists and chemists alike.

Acknowledgments are made here to Murex Welding Processes Limited, for permission to publish the results of the work, also to Dr. E. C. Rollason, Research Manager, for his encouragement.

² Haywood and Wood: "Metallurgical Analysis by Means of the Spekker Absorptiometer," 1944, Hilger.

The Metallurgist and Industry

WHILE marketing and salesmanship have their important place in Britain's drive to develop exports to pay her way, equal energy must be devoted to basic research which will ensure, not only a flow of new products, but a rising output and standard of existing products. In this field of standards of materials, the metallurgist has his part to play, said Dr. J. H. Jenkin, director of research of the Tube Investments Group of engineering industries, in his recent Presidential address to the Birmingham Metallurgical Society. The materials used by the engineer must, in the interests of public safety and the advancement of industry, be beyond doubt; in fact, all engineering developments have depended upon the ability of the metallurgist to find materials which will withstand the tremendous stresses, high temperatures, and other exacting demands, made by modern mechanisation.

Metallurgy has long since attained the dignity of a profession, and there are a number of learned societies which have contributed to the science of metals; but, up to the present, none has insisted upon members qualifying by examination. It has been an anomaly in British engineering development that, despite their responsible function, there has been no hall-mark to signify the skill and competence of the metallurgist.

Metallurgists throughout the country have realised this deficiency, and they have had their own "Working Party" operating to overcome it. The result is the estab-

lishment of a new professional body, The Institution of Metallurgists, which will be a qualifying organisation. The Institution will not overlap the work of the learned societies, but will ensure for the future that one who describes himself as a metallurgist shall have been judged by his peers as competent in the science and practice of working metals. It will provide a hall-mark in recognised grades and grant certificates of competence not merely of book knowledge, but of capacity to undertake responsible work.

From the metallurgist's point of view, this will give him the status and recognition which he has long merited, but that is not the primary consideration. What has happened is that British metallurgists have got together and established a professional body which will ensure both the maintenance and development of skill and knowledge of its members. This, said Dr. Jenkin, is a solid forward step in Britain's efforts to develop her industrial power.

Mining Journal

Annual Review Number, 1945

A REVIEW of progress, events and developments in various metal producing industries during 1944, including: Gold, Silver, Platinum, Nickel, Copper, Tin, Lead, Zinc, Cadmium, Magnesium, Aluminium, Mercury, Coal, Steel, Metallurgy and Equipment (Illustrations, statistics and Index).

Anon. + Various Authors. 112 pp. 12 x 9 ins. Price: 2s. 6d.

The Control of Tropenas-Converter Blowing by a Direct-Vision Spectroscope*

By S. T. Jazwinski, Dpl. Ing. Met.
(K. & L. Steelfounders and Engineers, Ltd., Letchworth).

The development of a converter flame during the blow and the appearance and disappearance of certain lines of the spectrum observed through the direct-vision spectroscopie are described. No attempt was made in these preliminary investigations to measure the wave-lengths of the bands, only their relative positions being recorded. It is concluded that a definite relationship exists between the bands in the flame spectrum and the composition of the metal in the bath. This leads directly to the application of the "electric eye" to the Tropenas converter to attempt a more rigid control of the process.

THE essential function of the converter in a steel foundry is to produce a bath of liquid metal at a suitable temperature which can subsequently be alloyed to the desired composition and can be easily cast. The oxidation of silicon, manganese, and carbon during the blow takes place approximately as shown in Fig. 1. Point E is the so-called "end of the blow," i.e., the point at which the wind should be shut off. An earlier shut-off results in underblown steel with high percentages of impurities, while a later shut-off results in overblown metal. As neither underblowing nor overblowing is desirable for producing a steel consistent with strict chemical and mechanical specifications, the end of the blow must be accurately determined.

Although the photo-electric cell has been applied in some modern plants to indicate this important end of the blow, the unaided human eye is still the means most widely used.

After observing over a period of time the appearance and changes of the flame of the converter during the blow, one can recognise the appearance of the "carbon flame"; this is a white, bright, unsteady, and fierce flame appearing nearly at the end of the blow. But one is still not sure of the end of the blow. It is claimed that the experienced human eye can judge the end quite accurately; this is true in most cases, but unfortunately not in all, because occasionally underblown or overblown heats are still made. This points to the need for an investigation by means of the miniature direct-vision spectroscopie.

The construction of this miniature spectroscopie is simple; it comprises an adjustable slit in the outer

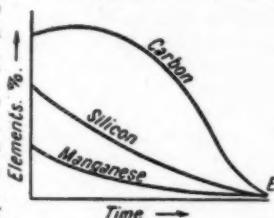


Fig. 1.—Oxidation of elements in the converter.

tube and a compound direct-vision prism in a sliding tube which can be moved forwards or backwards to focus the spectrum. The spectrum observed is due to gaseous atoms or ions. Atoms are activated by thermal energy and the electrons are partially withdrawn from the attracting nuclei. This means that some energy is lost by the atoms. The value of this change corresponds to emitted light of a definite frequency, which also is characteristic of the atom. As a result the so-called atomic spectrum is produced. In the converter flame the excitation of a few lines of the spectrum is observed. It is, not so pronounced as in the case of electric-arc excitation. By observing this spectrum the disappearance of constituents present in the bath can be demonstrated.

Changes in the Converter-Flame Spectrum

A summary of the successive changes in the spectrum with reference to the conditions of flame and sparks during an actual blow is given in Table I.

TABLE I.
CHANGES IN THE CONVERTER-FLAME SPECTRUM DURING A BLOW.
The figures indicate the number of minutes that had elapsed after the beginning of the blow when a certain band or bands appeared or disappeared

Exp. No.	Appearance of Yellow Band	Appearance of Green Bands—		Appearance of Red Bands	Disappearance of Bands	Wind Shut off	Blown Metal, Carbon %
		Faint	Clear				
1	12	—	37	37	40	40	0.08
2	12	30	32	32	37	37	0.08
3	9.5	33	36	38	43.5	43.5	0.09
4	10.4	24	33	—	40	40	0.08
5	4	23	27.5	27.5	32	32	0.07
6	9	33.5	33.5	35.5	38	38	0.09
7	10	27.5	32	32	39.5	39.5	0.09
8	9	22	28	28	34	34	0.08
9	12	28	39	39	42	43	0.05

* Overblown metal.



Fig. 2.—The start of the blow.



Fig. 3.—The boil.



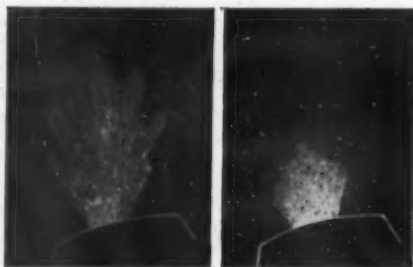
Fig. 4.—After ejects have ceased.

* Iron and Steel Institute, June, 1945 (advance copy).

At the beginning of the blow a very faint continuous spectrum was visible. At this moment the flame was dull red mingled with dense brown fume, and the sparks were ejected in a diverging stream with a number of clusters of scintillating sparks (Fig. 2).

The continuous spectrum became gradually brighter and stronger until the flame appeared more bright with less clusters of sparks and brown fumes. Then ejects were thrown out and a fine, weak, yellow band appeared in the spectrum. The outline of the flame now assumed the shape shown in Fig. 3, which marked the beginning of the boil. Sometimes the ejects continued for several minutes and became very violent. The yellow band was then very clear and steady.

After the ejects had ceased the flame became longer and brighter, with only a few sparks (Fig. 4). At this moment only a yellow band was visible. The flame then dropped and was duller, but it again increased in intensity and brightness. The spectrum now showed the appearance of a green band. At first it was so faint that its appearance was Fig. 5.—The carbon flame. Fig. 6.—The shortened flame at the end of the blow.



Then the flame became very bright, irregular-shaped and unsteady, with few sparks (Fig. 5); this is the well-known carbon flame. Two other green bands, on each side of the first one, and two red bands were then visible. Sometimes, if the flame was exceptionally brilliant, a blue band became visible. All these bands then appeared very clear and strong, but after an interval of $\frac{1}{2}$ –1 min. the red, green, and blue bands disappeared and left only the yellow band. At the same time the flame shortened (Fig. 6) and the wind was subsequently shut off. The relative positions of the bands were as shown in Fig. 7. In these preliminary investigations only the relative positions of these bands were determined; no attempt was made to measure the wave-lengths nor to prove that the yellow band indicated sodium, or the other bands manganese.

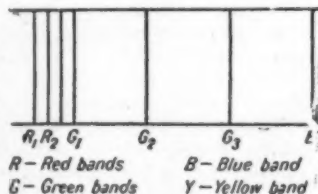


Fig. 7.—Positions of the coloured bands in the spectrum.

Discussion on the Observed Spectrum Changes

The explanation of the significance of these bands with respect to the extent of the oxidation of impurities in the metal requires more information.

The results for an overblown heat can be summarised as follows:

(1) The temperature of the blown metal will be lower. A rough estimation, based upon the assumptions that the wind is supplied at the rate of 40 cu. ft./sec. and the air finally attains a temperature of 1200° C., has shown that overblowing for one minute

will cause a temperature drop of about 70° C. for 2½ tons of metal.

(2) The analysis of the blown metal will show lower percentages of silicon, manganese, and carbon than that of properly blown metal, but, since oxidation after the end of the blow is not very appreciable (see Fig. 1), this difference will be very slight.

(3) Loss of metal will be increased by oxidation of the molten iron.

(4) Excessive wear on the lining can be expected, as the FeO tends to attack the lining and form silicates.

(5) The quantity of slag will be increased.

(6) The FeO content in the slag will be increased.

(7) Difficulty in casting may occur, especially on light and thin-section castings, owing to cold and sluggish metal.

(8) Defective castings may be produced, owing to the oxide inclusions in the molten metals.

Consequently, to prove that the disappearance of red and yellow bands really shows the true end of the blow other investigations must be carried out simultaneously with observations made with the aid of the spectroscope. Only by determining the temperature of the blown metal, the quantity and composition of the slag (before additions), and the metal losses, as well as making the spectroscopic observations, will all the necessary data be obtained.

Conclusions

(1) The time interval between the start of the blow and the appearance of the yellow band in the flame spectrum varies. This variation depends upon the temperature of the metal and of the converter lining, i.e., whether they are hot or cold. The appearance of the yellow band is generally accompanied by the commencement of ejects or boiling.

(2) The time interval between the appearance of the yellow band and green and red bands varies. This variation is due to the irregular composition of the metal tapped from the cupola, and the addition of ferro-silicon during the blow.

(3) The first green band always appears before the carbon flame. All the red and green bands are visible while the carbon flame exists.

(4) The end of the blow is reached when the red, green and occasional blue bands entirely disappear.

Data Sheets for Calculating Additions of Ferro-Alloys

DATA sheets with charts indicating a simple way to calculate additions of ferro-alloys to iron and steel are now available from St. Lawrence Alloys and Metals Ltd., Beauharnois, Quebec, Canada. Each of the eight data sheets available describes one of the chromium, manganese, or silicon alloys available from St. Lawrence, and contains a chart with instructions showing how to make simple, rapid, and accurate calculations on alloy additions.

These data sheets, part of a series of technical publications prepared by St. Lawrence Alloys and Metals Ltd., include charts printed in two colours to facilitate calculations in either the English or metric systems. All are punched for convenient binding. Copies of these sheets, now available in English, Spanish, French and Portuguese editions, will be sent to men concerned with the use of ferro-alloys or alloying metals. Requests should be written on a business letterhead and should specify the language desired.

The Application of Radiography to the Improvement of Foundry Technique

Rapid means of assessing results by radiography have enabled variations in production to be followed without cutting up castings

THE increase of scientific control in the foundry has assisted alterations in practice to improve the uniformity and character of castings produced. The skin and general appearance could be improved, but, until comparatively recently, the internal soundness was difficult to assess and improve, mainly because of difficulty in examining for this feature. The advent of radiography has, however, enabled the examination of the internal soundness of a casting to be undertaken non-destructively and, usually, much more easily and quickly than destructive methods and with less expense. This method of examination was discussed by Dr. R. Jackson,* at a recent joint meeting of the Manchester Metallurgical Society with the Iron and Steel Institute, in its application on the improvement of castings in a large foundry. The variations in manufacturing technique were not novel, using as they did the established principles of moulding and other practices, but the rapid means of assessing results by radiography enabled the working of the various alterations to be followed without the alternative expensive and cumbersome method of cutting-up. In addition, it was possible, by showing the moulder a radiograph of the results of his work, to enable him to realise the part which all his different operations played in arriving at a satisfactory casting.

A further point of value which has arisen from the work, described by Dr. Jackson, is the increase in the confidence with which castings can be regarded. It was formerly considered as axiomatic by the engineer that all forgings are sound and all castings are unsound, or at least are strongly suspect. It has now been demonstrated that castings can be made sound, that they can have an effective strength approaching that to be expected from a forging and that for certain purposes a casting may be better, cheaper, and more easily made than a corresponding forging fulfilling the same purpose.

In applying radiographic methods to the examination of steel castings it is more usual to use the film method, and Dr. Jackson confined himself to this technique, except for particular purposes. Although the method of preparing the radiograph is, in principle, simple, the interpretation of the results obtained requires considerable skill and experience. The variation in density of the film gives the information on which the radiographer determines the character or type of defects that may be present in the area of the casting under examination.

Excluding the variations in the thickness of the casting due to its shape, defects in the casting which can be found and differentiated by radiography may be classified as: (1) threadlike shrinkage; (2) shrinkage cavities; (3) blowholes and gas-holes; (4) slag inclusions; (5) sand inclusions; (6) alien-metal inclusions; (7) surface defects; (8) cracks (including pulls or tears). The recording of these defects on the X-ray film

depends on the difference in the thickness or density of the casting at that place. Dr. Jackson emphasised that the interpretation of a radiograph is a matter for the expert, and that at present an accurate quantitative evaluation is not possible.

The work done and the results achieved show that the use of radiography is able to be of great assistance in the development of steel castings. The usual types of defect met with in these castings, such as shrinkage, inclusions and cracks, can be found non-destructively if they make a difference in the effective thickness of the casting of about 2%, and, in some cases, if they are even smaller than this. It is possible by this method to differentiate the various types of defect and obtain some idea of their size and position. In addition, the examination gives a general view of the whole of the casting, and the distribution of the defects is disclosed, a factor of great assistance in finding the cause of the trouble, and in removing it.

The radiographic method of examination has the advantage over that of sectioning, since, in addition to being non-destructive, there is little chance, in a careful survey of the specimen, of serious defects being missed. It is self-evident that in sectioning a casting there must be a very grave danger of defects being overlooked, unless they are so serious that they extend over a considerable volume of the casting.

For the usual purposes of determining the existence and location of any defects, the radiograph is, in general, easily interpreted by anyone with a knowledge of the geometry of the specimen and of the direction of the X-ray beam when the radiograph was taken. The technique of taking the radiograph and its interpretation in detail are, however, matters for the expert, and by a faulty procedure it is readily practicable to obtain from a defective casting a radiograph on which the specimen appears quite sound.

The value of the employment of X-ray equipment in obtaining sound castings is evidenced by the improvement shown in the various examples which were quoted, as one fault after another has been eliminated from the manufacturing process. It may, in fact, be quite truly stated that, in the case of some of the castings mentioned by Dr. Jackson, the required standard of soundness could not have been obtained without the free use of this tool.

The effect upon the use of castings of the increase in soundness should be profound. The use of castings has frequently been based on the idea that a casting is the poorest form of metal, and can only be relied upon if there is a considerable bulk of metal in excess of that which would normally be required, as, for example, in the case of a forging. If the casting can be shown to be sound when required, then the need for many of the additional factors of safety may be removed; the casting may then compete (on a basis of similar weight) with the forging, resulting, in general, in a considerable

* See Paper No. 13/1945 of the Steel Castings Research Committee presented by Dr. Jackson at the Annual General Meeting of the Iron and Steel Institute, May, 1945.

saving in cost. There may arise the need for more accurate interpretation of the effect of faults upon the strength of the article, as small defects which are approaching the limit of visibility by the radiographic method may have a vanishingly small effect upon the strength of the part.

Whilst it is evident that radiographic technique can be applied to the determination of internal defects, there is still a considerable gap in our knowledge of the influence of the defects on the subsequent useful performance of the casting. Even with regard to the interpretation of the radiograph, there may be uncertainty in defining the exact size of a defect. Little has yet been published on the quantitative effect of any specific type of defect on the strength of a casting. This

difficulty is overcome, to some extent, in the examination of welds in plates by establishing a series of standard radiographs which are used for assessing the value of the examined weld. So far, the complexity of castings and the lack of knowledge of what constitutes a defective casting have prevented the widespread application of this method to the foundry. There is much scope here for work on the influence of defects upon the strength of castings, provided that the shape, position and size of the defects are known. Standards of assessment are required to be known in terms of these last-named factors. They must also be correlated with the mechanical properties of the casting as a whole and with its ultimate performance in service. The results of some effects in these directions were presented.

The Acid Corrosion of Magnesium

By G. E. Coates, M.A., B.Sc.

THE first part of a general study of the mechanism of the corrosion of magnesium is described by G. E. Coates in a recent paper.* The wet corrosion of magnesium is commonly regarded as essentially an electrochemical process, and the subject is, therefore, most profitably investigated by electrochemical methods. The saline corrosion of magnesium generally proceeds with the formation of hydroxide or other obstructive films, which cause local corrosion and render measurements of current density difficult if not impossible. Since it was intended to examine the subject quantitatively, attention was given first to acid corrosion, which is uniform and therefore amenable to exact treatment. The work has been carried out in the Metal Research Station of the Magnesium Metal Corporation, Ltd.

A consideration of previous work on the acid corrosion of magnesium strongly suggests a diffusion-control mechanism. This necessarily implies the existence of a state of concentration polarisation which has been overlooked in the Gatty-Spooner interpretation of the potentials of the corroding metal. With this exception, the latter theory is supported by a recent calculation of the standard electrode potential and by the behaviour of magnesium in acid solutions in light and heavy water. A recent study of concentration polarisation indicates the possibility that the corrosion rate of magnesium in acids may be intimately related to the critical current density effect.

The purpose of the experiment described in the present paper was to measure the hydrogen overvoltage of magnesium with the object of interpreting the electrode potential of the corroding metal; to measure the corrosion rate of magnesium in various acids; and to obtain a quantitative interpretation of the corrosion rates with the help of critical current density measurements.

The hydrogen overvoltage of magnesium, measured in 0.2N-sulphuric acid by the new electrical technique of Hickling, is high, with a tendency towards a constant value of about 1.3 V. at current densities greater than 0.7 amp./sq. cm. In its overvoltage properties magnesium is, therefore, similar to other non-catalytically active metals, such as tin, lead, cadmium, and mercury.

Measurements of the corrosion rate of magnesium in acids and of the concentration-polarisation properties of the same acids suggest the following mechanism for acid corrosion. The standard potential indicates great electrochemical activity and a very high tendency to go into solution. Since the standard potential exceeds any possible value of the potential (including hydrogen overvoltage) necessary to discharge hydrogen ions, the corrosion rate is limited by some factor other than a balance between "solution pressure" and hydrogen-discharge potential of the type familiar in the acid corrosion of, for example, iron and zinc. Previous work on concentration polarisation considered together with the studies on concentration polarisation mentioned indicates that the acid corrosion of magnesium is limited by concentration polarisation, i.e., diffusion, effects in the solution. Magnesium ions escape into the solution at the maximum rate, but to maintain electrical balance this must be equal to the rate at which hydrogen ions are discharged at the metal. An almost unlimited supply of ions is available from the dissociation of water in strongly alkaline solutions, in which water has a high buffer capacity²² (the electrode pH may become alkaline by concentration polarisation), but the low solubility of magnesium hydroxide and the consequent limitation of the pH in the immediate vicinity of the metal surface to about 11 limits this source, since the buffer capacity of water is appreciable only in more alkaline solutions. Hence the corrosion rate is equivalent to the current density, which adjusts itself to produce a degree of concentration polarisation just sufficient to prevent any more than transitory formation of magnesium hydroxide at the metal surface. In dilute solutions of strong acids this entails a degree of concentration polarisation of about 0.6-0.7 V. The increase of corrosion rate with acid concentration is due to the higher current density required to produce this degree of concentration polarisation, the increase of corrosion rate being faster than a linear function of acid concentration on account of the effect of gas evolution (stirring) on the thickness of the diffusion layer. Over wide ranges the logarithm of the corrosion rate varies linearly with the logarithm of the acid concentration. An additional effect obtains in corrosion by solutions of ammonium salts due to the liberation of free ammonia in the diffusion layer.

* *Jour. Inst. Metals*, 1945, **71**, 457-480.

A Method of Revealing the Micro-structure of Nickel Deposits on Steel

By R. Stokes

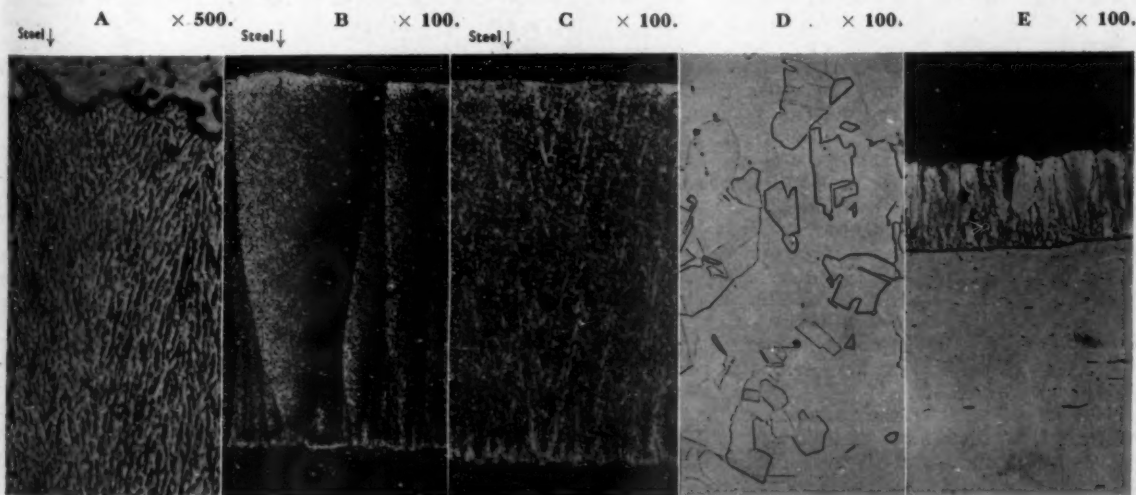
THE micro-examination of nickel deposits on steel for the purpose of checking the thickness, adhesion or porosity is a common laboratory operation and it is usual to examine the samples in the unetched condition or with the base metal only etched. Recently, however, during the course of an investigation on hard nickel deposits it was desired to examine the micro-structure of the nickel, and failing to find a reagent recommended specifically for this purpose in any literature available, an attempt was made to evolve a suitable etching procedure.

The etchant first used was that commonly prescribed for pure nickel, viz., equal volumes of nitric acid and glacial acetic acid, but it was found that while this etched the nickel there was severe attack on the steel, causing a pronounced step effect at the interface, and partial decomposition of the plastic mounting material giving rise to serious staining. Other reagents based on strong mineral acids gave rather similar results. An electrolytic etch recommended in the *ASM Handbook* and consisting of acetic acid 5% and nitric acid 10% by volume, in water, was tried but it was found that the attack was concentrated mainly on the steel, only slight etching of the nickel taking place. Reagents containing copper in solution, such as the B.N.F. Jet Test Solution for Nickel, gave rather better results but etching of the deposit was rather irregular and subject to staining.

As a result of these preliminary experiments it was realised that to get satisfactory results an etching reagent was required which would etch the nickel only or would etch the nickel and the steel at approximately the same rate. The following procedure was evolved and found to give good results:—The specimens mounted in plastic were polished in the usual way being finished on a rotating disc covered with broadcloth, alumina being used as an abrasive. After examination, to

ascertain if free from scratches or step effect between nickel and steel, the samples were given a further light polish to remove any oxide film which may have been formed. While still wet from washing, the samples were transferred to a "Selryt" pad moistened with strong ammonium hydroxide and subjected to a light polish attack by hand for 1-5 minutes, being subsequently washed in water and alcohol and dried. By this procedure it was possible to etch the nickel deeply with only slight attack of the steel or of the interface. With the hard nickel deposits no definite crystals were resolved, but a type of microstructure was revealed which it was thought indicated the mode of growth of the deposit. A typical example is shown by photomicrograph, reproduced at A, which illustrates a fan-like divergent growth emanating from small irregularities on the surface of the steel. At lower magnifications, under bright field illumination, the deposits tended to exhibit a matt appearance but, under plain polarised light, pseudo-grains were revealed which varied in form with the hardness of the deposit. Typical examples are illustrated by photomicrographs, reproduced at B and C, which show, respectively, samples with a diamond pyramid hardness of approximately 480 and 400. It will be noted that in the harder sample the "grains" are large and extend in some instances completely across the deposit, while in the softer sample the "grains" are small and more interrupted (thickness of deposit, 0.024 in.).

In order to check the ability of the etching procedure to reveal a true crystal structure, a sample of annealed pure nickel rod and of dull nickel plating were examined after etching as described above. A typical twinned polygonal structure was developed in the nickel rod, a representative field being shown by photomicrograph, reproduced at D. The dull nickel deposit displayed fairly



large columnar crystals, some of which showed evidence of twinning, as illustrated by photomicrograph, reproduced at E; the angular ends of the crystals which give the deposit its dull appearance are well shown. (The diamond pyramid hardness of this deposit was approximately 130).

It is not thought likely that a full appraisal of the physical properties of a nickel deposit may be made from the appearance of its microstructure, but it is considered possible that useful indications as to its mode of formation and probable hardness may be obtained, particularly with the thinner deposits which do not lend themselves so readily to normal mechanical tests.

Forthcoming Meetings

INSTITUTE OF MECHANICAL ENGINEERS.

- Nov. 30 Discussion on Pistons and Piston Rings, centreing on short papers, introduced by J. S. Courtney-Pratt, B.E., G. K. Tudor, B.E., and B. Pugh, Ph.D., B.Sc. At Storey's Gate, at 5-30 p.m.

SCOTTISH BRANCH.

- Dec. 6 Thomas Hawksley Lecture, "The Scientist at War," by Sir Edward Appleton, K.C.B., D.Sc.

INSTITUTE OF BRITISH FOUNDRYMEN.

SHEFFIELD BRANCH.

- Nov. 26 "The Technological Principles of Casting Designs," by Prof. V. M. Shectopal, presented by W. H. Salmon. At the Royal Victoria Hotel, at 7-0 p.m.

BIRMINGHAM BRANCH.

- Nov. 28 Short papers on "Economical Quick Methods of Preparing Plate Patterns for Limited Quantity Production." At James Watt Institute, at 7-30 p.m.

LONDON BRANCH.

- Nov. 28 "The Technological Principles of Casting Design," by Prof. V. M. Shectopal, presented by C. H. Kain. At the Charing Cross Hotel, at 7-30 p.m.

LANCASHIRE BRANCH.

- Dec. 1 "Secondary Aluminium Casting Alloys in War and Peace," by F. Smith.

SHEFFIELD METALLURGICAL SOCIETY.

- Nov. 27 "Some Problems on the Heat-Treatment of Steel," by Dr. R. Hunter. Sheffield Metallurgical Club, at 7-0 p.m.

- Dec. 4 Joint Meeting with the Iron and Steel Institute. Dr. W. J. Rees will present a paper on "Mould and Core Sands and Washes, and Parting Powders."

- Dec. 11 Address by Dr. C. Sykes, F.R.S.

SOCIETY OF INSTRUMENT TECHNOLOGY.

- Dec. 13 "Automatic Temperature Control of Jacketed Pans," by G. H. Farrington. At the London School of Tropical Medicine.

STAFFORDSHIRE IRON AND STEEL INSTITUTE.

- Dec. 14 Open discussion: "How far Can Iron Castings Replace Steel?"

INSTITUTE OF METALS.

SCOTTISH SECTION.

- Dec. 10 "Petroleum Production in the United Kingdom," by C. A. P. Southwell.

IRON AND STEEL INSTITUTE.

WEST OF SCOTLAND.

- Dec. 14 "Steel From the Users' Point of View," by J. Arnott.

LINCOLNSHIRE.

- Nov. 27 "Sinters and Sintering, Part I," by Dr. H. L. Saunders and Dr. H. J. Tress. At Scunthorpe Technical School, at 7-30 p.m.

Recent Appointments

DR. WILLIAM T. GRIFFITHS who succeeded Mr. David Owen Evans as Chairman of The Mond Nickel Company Limited, has been appointed Vice-President and Director of the International Nickel Company of Canada, Limited. As one of the country's most distinguished metallurgists, Dr. Griffiths has made several visits to the United States during the war on behalf of the Government and he has been responsible for the research activities of the nickel industry for many years. He has been President of the Institute of Metals for the past two years.

MR. G. W. LACEY, B.Sc., A.R.I.C., has been appointed General Sales Manager of the British Aluminium Co. Ltd., and has relinquished his appointment as Controller of Light Metals in the Ministry of Aircraft Production. As General Sales Manager, Mr. Lacey will be responsible for the Sales Division of the Company. He will be located at the Head Office, Salisbury House, London Wall, E.C.2.

MR. G. A. ANDERSON, B.A., who recently relinquished his appointment as Deputy Controller of Light Metals to rejoin the Company has been appointed Deputy General Sales Manager. The other appointments to be made are: Mr. E. A. Langham, Sales Manager; Mr. A. W. Langham, Sales Planning Manager; Mr. H. R. Cundell, Development Manager; Mr. R. M. Warrington, Assistant Development Manager; and Mr. L. Hart, Assistant Sales Planning Manager. Mr. H. Cousins will have the title of Publicity Manager and Mr. W. R. Platt will remain as Assistant Sales Manager.

DR. L. B. PFEIL has been appointed Manager of the Research and Development Department of the Mond Nickel Company Ltd., in succession to Dr. W. T. Griffiths, who was recently appointed Chairman of the Company. The post of Assistant Manager, previously occupied by Dr. Pfeil, has been filled by Mr. F. Dickinson, B.Sc. Mr. H. W. G. HIGNETT, B.Sc., has been appointed head of the Research and Development Department Laboratories at Wiggan Street, Birmingham.

BRIGADIER A. LEVESLEY, O.B.E., M.C., M.I.Mech.E. has been appointed General Manager of the steel foundry and ancillary departments of Edgar Allen & Co. Ltd. Joining the staff of Edgar Allen & Co. Ltd. in 1910, Brigadier Levesley became technical assistant to the Works Manager.

MR. G. WESLEY AUSTIN, O.B.E., M.Sc., has been appointed Goldsmiths Professor of Metallurgy in the University of Cambridge.

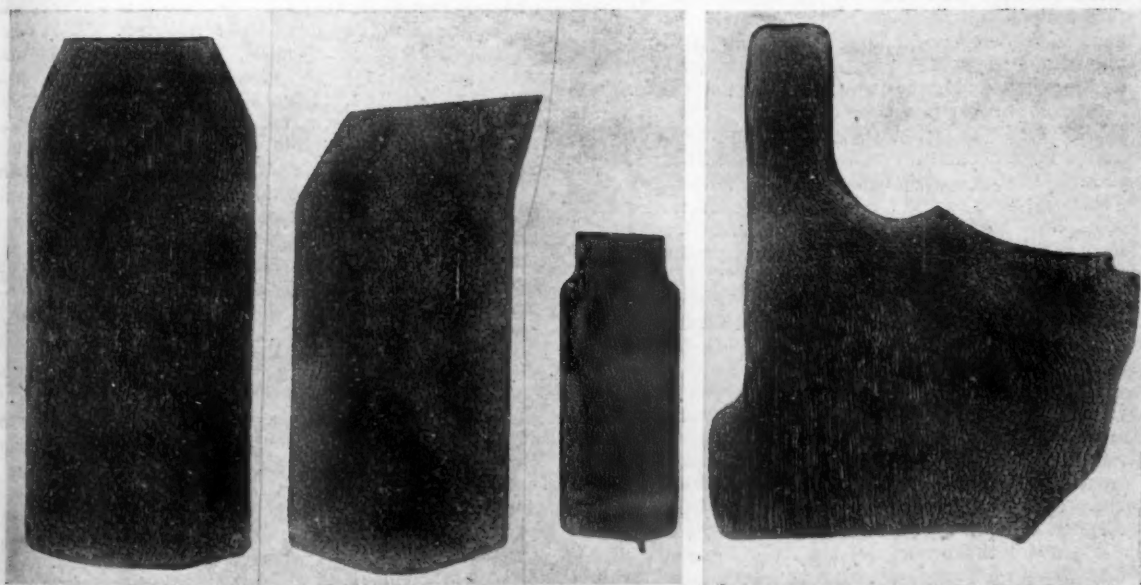
MR. B. ALLEN has been appointed Technical Representative by Hadfields Ltd. for all their colliery equipment throughout the country. Mr. Allen is a qualified mining engineer and fully conversant with up-to-date mining practice. He is operating from the Company's East Hecla Works, Sheffield.

Nature Printing Aluminium Alloy Forgings

A Rapid and Economical Method



Macro-sections photographed to show grain flow.



Same macro-sections nature printed to show grain flow. Reduced to two-thirds actual size for convenience in reproduction.

RECENTLY it has been necessary to check the forging flow line disposition of large numbers of light alloy forgings prior to acceptance by The de Havilland Aircraft Co., Ltd., Hatfield, and this has resulted in a volume of work which has rendered desirable some reduction in the amount of labour and materials expended. With this in view, it was considered desirable to investigate the possibility of nature printing

macro-sections of forgings to show grain flow line. A suitable technique would have the advantage that no photography would be involved and the machined finish necessary would not be so fine as that required for photography. An additional advantage of nature printing is the production of actual sized grain flow lines, whereas photographs involve reduction to accommodate the image on the plate.

Macro-etchants

Various macro-etchants were tried in attempts to produce a deep etch suitable for printing; the etchant finally selected was used and the resulting prints compared with photographs of the same sections; specimens of both are reproduced in the accompanying illustrations.

The etchant finally evolved was as follows:—

75 grms. ferric chloride.

25 grms. cupric ammonium chloride, in

1 litre water.

The etchant is used hot at a temperature of 80° to 90° C., the section being immersed for a period of 6 to 10 minutes with a new bath.

Adherent brownish red deposit is removed by rubbing with a rag and hot water, any further remaining after this being removed by immersion in 45% nitric acid solution for approximately 1 minute at room temperature, or until there is no further effervescence.

War Work of the British Thomson-Houston Co. Ltd.

IN this brief survey of the outstanding war achievements of The BTH Co., Ltd., it should first be pointed out that many of the Company's peacetime products were indirectly required to meet the war effort. A very large amount of direct armament production was carried out, however, much of which, by utilising the research and engineering facilities of the BTH was either designed by the Company itself, or in close collaboration with various Government Departments.

There is no doubt that the most phenomenal achievement of the war was Radar, in which the BTH Company played an important part, being responsible for the development and engineering of all kinds of Radar sets for use at sea, in the air, and on land. It is interesting to note that Radar equipment, to which the BTH made major contributions, was an important factor in the sinking of the German battleships *Scharnhorst* and *Bismarck*, and in the victory of the Battle of Cape Matapan. Earlier in the war and before Radar came into such wide use, several thousand predictors were made by the BTH Co.

Also, one of the most noteworthy events during the war was the use of jet propulsion for aircraft. The jet engine was first developed by the BTH Company in conjunction with Air Commodore Whittle, and after exhaustive experiments, beginning in 1936, an engine, built by BTH Co., was successfully flown for the first time in May, 1941, in a plane built by the Gloster Aircraft Co., Ltd. In September 1941 a similar engine, manufactured at Rugby, was sent by the BTH Co., to their associated Company in the U.S.A.—the General Electric Company (of New York) for them to study.

Following the development of the jet engine, work has been done on the gas turbine for which there are considerable future possibilities, particularly in the field of ship propulsion.

The danger of the acoustic mine was defeated with the help of BTH Co., and for this purpose the Company designed and developed over 800 oscillators. The work on these oscillators was put in hand immediately following the introduction by the Germans in December, 1940, of the acoustic mine, and deliveries were commenced in March, 1941. The first oscillator made was the Fessenden type, but although this met with success, it suffered from certain inherent disadvantages in design.

After washing the surface may be used for nature printing, but further treatment is necessary for complete cleanliness of the surface. This is achieved by immersion in 20% caustic soda solution at room temperature for 1 minute, followed by a dip in 45% nitric acid solution. A hot water wash followed by drying completes the process. A deep etch results, and nature prints may then be taken in the conventional manner.

Conclusions and Remarks

A satisfactory macro-etchant has been evolved for producing an etch on aluminium alloy forging sections deep enough for the reproduction of nature prints. So far only the forgings manufactured from materials to Spec. DTD. 364A, L.40 and L.45 have been tested, there is reason to believe, however, that a wide range of materials may be amenable to this technique.

The BTH Co. therefore proposed the use of the inductor type oscillator, and after successful demonstrations, the device was put into production and subsequently into successful service against the acoustic mine in 1941.

The electric torpedo was another outstanding product of the BTH Co. This torpedo represents a radical change from the normal type, in spite of the fact that no manufacturing technique for the device existed in this country when BTH was asked to undertake the work. Moreover, the British model had to be made suitable for over water discharge (the German torpedo was not), and also lighter in weight to enable a heavier war-head containing more explosive to be adopted. Many difficulties had to be overcome before production was commenced on a large number of the torpedos, in a building specially erected and equipped for the purpose.

Only a few days ago H.M. Stationery Office issued a pamphlet releasing details of the atomic bomb, in the development of which the BTH Co. also gave assistance.

Finally, mention must be made of the thousands of Wellington bomber parts, aircraft magnetos, auto-timing devices, switches, motors, generators, compressors, servo motors for auto-pilot control, amplidyne for servo-position control, aircraft cameras, tank components, mines and shells, which were manufactured by the BTH Company.

New Chemical Substance—Styralexy

A New chemical substance, made of butadiene and styrene, principal ingredients used in making synthetic rubber, but developed by a different chemical treatment, has been announced by the Dow Chemical Co. It is named "Styralexy" and remarkable properties are claimed for it which enables this material to be used for a wide variety of purposes. According to Dr. W. H. Dow it can be used to make everything from insulation on electric wires to water pipes, unbreakable cigarette cases, toys and door knobs. Although it is so light that it floats on water, it can be used for dent-proof decorative floor covering which wears like iron. The substance which can be machined like metal, sawn like wood or extruded and moulded like plastic, can be produced in all colours simply by using appropriate dyes and pigments in the mixing. Among experimental uses already claimed for this material are shoe heels, refrigerator trays, door mats, motor-car running boards, tool handles, electrical tape and pipe fittings.

A Metallurgical Study of German Aircraft Engine and Airframe Parts

This report constitutes a summary of further data, resulting from the metallurgical examination of German aircraft engine and airframe parts by the Aero-Components Sub-Committee of the Technical Advisory Committee of the Special Alloy Steel Committee formed for that purpose.

The types examined represent a comprehensive range of various types of German aircraft which have fallen into the hands of the R.A.F. from 1942 onwards.

The principal object of these investigations was to obtain data on the types and quality of materials used, methods of manufacture, efficiency of the heat-treatment to which the parts have been submitted, together with any other information which might prove of value, as, for example, details of the finish. Further, the influence of restrictions, due to our blockade, on German procedure and selection of materials was kept in mind. Attention was given chiefly to engine parts but a number of airframe and miscellaneous components were included. Special features concerning design had been noted in certain instances, but these were not

the primary object of the investigations. The Sub-Committee responsible for these investigations and for this report comprise: Mr. S. Barraclough, United Steel Companies, Ltd.; Mr. H. Bull, Messrs. Brown-Bayley's Steelworks, Ltd.; Mr. H. H. Burton, the English Steel Corporation, Ltd.; Mr. W. J. Dawson, (Chairman), Hadfields, Ltd.; Dr. R. Genders, M.B.E., S.T.A.M., Ministry of Supply; Mr. H. J. Hipkins, Royal Aircraft Establishment; Mr. N. H. Mason, R.A.E., Farnborough; Mr. D. A. Oliver, Messrs. Wm. Jessop and Sons, Ltd.; Mr. L. Rotherham, Thos. Firth and John Brown, Ltd.; Dr. H. Sutton, Ministry of Aircraft Production; Miss M. K. Walshaw, Secretary, Brown-Firth Research Laboratories.

The work included in this report embraces the results of investigations carried out as a continuation of the data already published.* It has been carried out meticulously. Naturally in this Report no comparisons are made with corresponding parts in British and American Aircraft, neither are certain aspects which our investigations have shown to be open to criticism emphasised.

Section V.—Cylinders and Cylinder Liners

SINCE the publication in 1942 of our first report covering the results of the metallographic examination of a number of cylinders and cylinder liners, a further sixteen—all of German origin have been examined. They were of the following types, of which typical photographs are shown herewith*.

Liquid cooled cylinder liners from

Junkers Jumo 211 engine—see Fig. 1.

Daimler Benz 601 N. engine—see

Fig. 2.

Mercedes Benz DB.605 A/1 Engine

—see Fig. 3.

Air cooled cylinders from

BMW 801 engine—see Fig. 4.

The machined finish of all the samples was good and none showed any appreciable scoring of the bore surface, which possessed the usual honed appearance.

The external surface of the cylinder liners from the Junkers Jumo engines had been chromium plated, and as described in the first summary, this had been done on a previously smooth ground surface with no further preparation after plating. The thickness of the plating was about 0.001 in.

As shown by the accompanying illustrations, the cylinder liners of Mercedes and Daimler Benz types had a smooth ground outer surface, whereas the air cooled cylinders of B.M.W. types had been black enamelled. In these latter cylinders, provision was made for the thermo-couples described in the first summary, but none were fitted.

A full list of the cylinders and liners with their chemical analyses is given in Table I, and reference will show that steels of two compositions had been used. All of the air cooled cylinders from the B.M.W. engines had been made from a 1½% chromium steel, as in the first summary, and a similar steel had been used for the cylinder liners, except in three instances, Item Nos. 210, 246 and 260, for which a plain carbon steel had been employed. It will be noticed, however, that in those instances the carbon had been raised to 0.6 per cent.

The reason for the omission of chromium from the steels used for these cylinders and liners was not apparent. Economy of that metal does not appear to have been necessary. Nor does the carbon steel appear to have come into general use, as the

latest liner, Item No. 301, had been made from the chromium steel. In the first summary, it was shown that the Fiat manufacturers had employed a carbon steel, but it is not likely that this fact has much significance. The question of cylinder wear is important but the life of the cylinders was probably not long enough to show that the plain carbon steel was inferior.

With one exception, Item No. 246, the sulphur and phosphorus contents remained low, and the steels appeared to have been made by the basic electric furnace. Even so, the cleanness varied considerably from clean to rather dirty, and two inclusion counts of over 80 were obtained.

Method of Manufacture

All of the samples had been made from tube, and all had been heat treated by hardening and tempering. But, whereas the cylinders and liners of chromium steel possessed completely sorbitic microstructures, the three samples made from carbon steel possessed structures of sorbitic pearlite with a discontinuous ferrite network. None of the samples showed any special treatment of the bore surface.

* "A Metallurgical Study of German and Italian Aircraft Engine and Airframe Parts," 1943, The Kennedy Press, Limited.



Fig. 1.—Liquid cooled cylinder liner from Junkers Jumo 211 engine.



Fig. 2.—Liquid cooled cylinder liner from Daimler Benz 601 N engine.

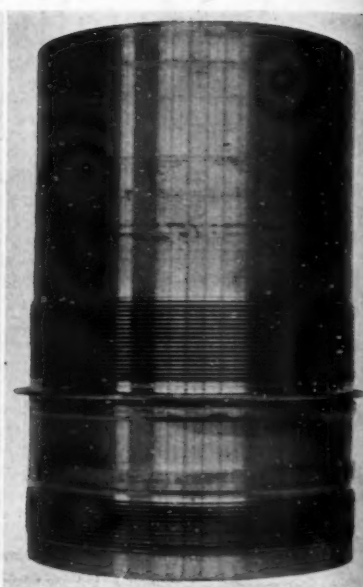


Fig. 3.—Liquid cooled cylinder liner from Mercedes Benz DB.605 A/1 engine.

TABLE I.—CYLINDERS AND CYLINDER LINERS.—CHEMICAL ANALYSES.
LIQUID COOLED CYLINDER LINERS.

Item No.	Engine	C	Si	Mn	S	P	Ni	Cr	Mo
155	Daimler Benz 601 N...	0.45	0.29	0.53	0.011	0.023	0.11	1.40	0.05
159	Junkers Jumo 211 J.1	0.45	0.33	0.56	0.009	0.017	0.07	1.55	0.05
181	Junkers Jumo 211 J.1	0.50	0.31	0.61	0.012	0.018	0.10	1.52	0.05
210	Junkers Jumo 211 F.1	0.40	0.29	0.66	0.017	0.013	0.04	0.14	0.02
226	Junkers Jumo 211 F.1	0.44	0.30	0.58	0.013	0.017	0.11	1.22	0.05
232	Mercedes Benz DB 605 A/1	0.44	0.22	0.46	0.009	0.009	nil	1.61	0.01
246	Junkers Jumo 211	0.59	0.33	0.54	0.028	0.026	nil	0.15	0.03
260	Mercedes Benz DB 603	0.65	0.33	0.70	0.007	0.014	0.05	0.12	0.03
290	Daimler Benz 605	0.46	0.26	0.42	0.018	0.023	0.07	1.49	0.01
301	Junkers Jumo 213 A1	0.51	0.32	0.55	0.010	0.011	0.12	1.39	0.04

AIR COOLED CYLINDERS

Item No.	Engine	C	Si	Mn	S	P	Ni	Cr	Mo
164	BMW 801-C/2	0.50	0.28	0.68	0.024	0.015	0.35	1.50	0.03
204	BMW 801-A/2	0.44	0.30	0.69	0.018	0.018	0.12	1.42	0.02
215	BMW 801-A/2	0.42	0.25	0.51	0.012	0.010	0.12	1.55	0.03
240	BMW 801-A	0.46	0.26	0.46	0.005	0.015	0.11	1.55	0.01
284	BMW 801-G	0.50	0.46	0.75	0.010	0.013	0.31	1.30	0.04
296	BMW 801-G/2	0.45	0.27	0.63	0.014	0.011	0.06	1.37	0.04

Hardness and Tensile Strength

As the cylinder liner of Item No. 210 was the first to show a change of composition from the 1½% chromium steel to a 0.6% carbon steel, a longitudinal tensile test piece was prepared from the wall of that cylinder.

Tensile (0.075 in. × 0.533 in. × 0.8 in. gauge length).

Yield Point .. 40.0 tons per sq. in.

Max. Stress .. 59.9 " " "

Elongation % 23.1

Contraction % 45.0

This was the highest tensile strength of all the samples examined for this summary, but an early cylinder from B.M.W. 132 K—Item 12 of the first summary—possessed a tensile strength of 67.6 tons per sq. in. The tensile strengths of the remaining cylinders and liners were computed from hardness determinations. The range was from 45 to 57 tons per sq. in.

General Remarks

These further samples showed that the high standard of quality and work-

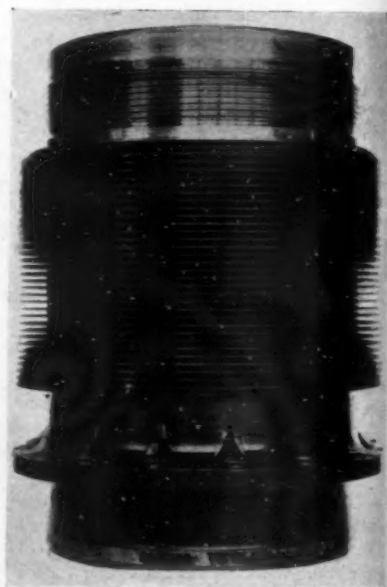


Fig. 4.—Air cooled cylinder from B.M.W. 801 engine.

manship described by the first summary had been maintained.

A change of composition from a 1½% chromium steel to a plain carbon steel of slightly higher carbon content had been made, but this appeared to have been more in the nature of an experiment than a necessity.

Section VI—Inlet and Exhaust Valves

SINCE the publication of the first report on enemy aero components the following valves have been examined.

Jumo 211 series—

8 inlet and 8 exhaust valves.

(Item Nos. 94, 118, 128, 162, 186, 211, 230 and 249).

Jumo 213 series—

1 inlet and 1 exhaust valve.

(Item No. 304).

BMW 801 series—

7 inlet and 7 exhaust valves.

(Item Nos. 135, 169, 206, 217, 243, 258 and 269).

Mercedes Benz DB series—

4 inlet and 6 exhaust valves.

(Item Nos. 157, 163, 237, 264 and 295).

Japanese Kinsei 44—

1 exhaust valve.

(Item No. 221).

A summary of the data obtained is given in Table I.

Chemical Composition

Inlet Valves. With one exception (Item No. 94) all the inlet valves examined were of silicon-chromium steel equivalent to that covered by Specification DTD.13B. The exception was from a Jumo 211A engine which proved to be made from a high carbon stainless steel (1.7% carbon, 11.9% chromium).

Exhaust Valves. The earlier exhaust valves examined (Item Nos. 94, 118, 135, 169, 206, 217, 243 and 163) were manufactured from steel of the DTD. 49B type (13% nickel, 15% chromium, 2½% tungsten), but with one exception (Item No. 264) the more recent valves have been of a steel approximating to DTD.282. This change represents a decrease in alloy content of 5% nickel and 1½% tungsten, a decrease which is offset to a certain extent by a 3% increase in the chromium content. The presence of small amounts of titanium and zirconium were noted in several of the valves.

Constructional Details

Inlet Valves. The Jumo 211 and BMW 801 series of inlet valves were in all cases solid. They had been formed by a hot heading operation and were locally hardened at the tappet end.

The Jumo 213 and Mercedes Benz DB series were of a slightly different construction. The stems of these valves had been drilled out through the head, which had then been sealed off by a plug weld. The hollow stems contained no coolant but were locally hardened at the tappet end.

Exhaust Valves. The exhaust valves examined contained sodium coolant and in every case stellite type of material had been deposited round the

seat and at the tappet end. None of the valves had been nitrided.

The stems of the Jumo 211 series were hollow and the heads partially hollow. A variety of methods of drilling this type of valve appear to have been adopted. In one instance (Item No. 128) the head was pierced, in another the tappet end had been pierced (Item No. 162) and in a third (Item No. 118) both ends had been pierced during drilling.

The Jumo 213 series of exhaust valves had hollow stems and fully hollow heads. The slugs had been drilled from the head end before forging and the valve head sealed off by welding.

The general construction of the BMW 801 valves was similar to the Jumo 213 valves except that the drilling had been carried out from the tappet end and the stem sealed by a local forging operation.

The Mercedes Benz DB series of exhaust valves resembled closely the corresponding inlet valves, the heads being solid and the stems hollow. With one exception (Item No. 157) they had been drilled from the head end.

The only Japanese exhaust valve examined was from a Kinsei 44 engine and proved to be very similar to the BMW 801 type.

TABLE I.

Item No.	Type of Engine	Date plane brought down	Type of Valve	Chemical Composition—weight %														Diamond Pyramid Hardness	Constructional Details
				C	Mn	Si	S	P	Ni	Cr	W	Co	Mo	Cu	Al	Other Elements V.			
94	Jumo 211A	Feb., 1940*	Inlet Exhaust	1.71 0.45	0.47 0.74	0.31 1.66	0.031 0.007	0.021 0.019	0.13 13.4	11.9 16.3	Nil 2.58	— —	Nil Nil	0.04 0.09	0.022 0.026	0.04 0.04	— —	— —	
118	Jumo 211F1	—	Inlet Exhaust	0.46 0.49	0.38 0.73	2.72 1.38	0.020 0.023	0.017 0.022	0.26 13.0	8.52 15.4	Nil 2.34	— —	0.23 0.13	0.15 0.20	— —	— —	242/283 218/238	Solid. Stem: drilled from both ends. Head: partly hollow.	
128	Jumo 211F1	—	Inlet Exhaust	0.40 0.32	0.44 1.02	3.27 3.13	0.026 0.027	0.012 0.014	0.3 9.28	10.9 19.8	Nil 1.30	Nil 0.29	0.03 0.10	0.04 0.04	0.008 0.011	— —	247/339 240/319	Solid. Stem: drilled from head end. Head: partly hollow.	
162	Jumo 211J1	April, 1942 (June, 1941)*	Inlet Exhaust	0.40 0.41	0.42 1.09	3.40 2.76	0.019 0.024	0.016 0.017	0.10 9.48	9.8 18.9	Nil 0.93	Nil Nil	Nil Trace	0.10 0.07	0.013 0.009	— —	249/289 253/304	Solid. Stem: drilled from tappet end. Head: partly hollow.	
186	Jumo 211J1	August, 1942	Inlet Exhaust	0.42 0.35	0.30 0.82	2.58 2.66	0.027 0.026	0.015 0.020	0.29 8.68	10.7 19.9	Nil 1.11	Nil Nil	0.10 0.20	0.15 0.14	0.026 0.026	— —	— —	— —	
211	Jumo 211F1	Jan., 1943	Inlet Exhaust	0.40 0.39	0.47 1.31	3.48 2.86	0.010 0.015	0.012 0.030	0.11 9.12	9.32 18.5	Nil 1.35	Nil Nil	Nil Nil	0.09 0.10	0.005 0.013	— —	— —	— —	
230	Jumo 211F1	April, 1943	Inlet Exhaust	0.43 0.36	0.70 1.05	2.74 2.52	0.023 0.008	0.018 0.016	0.27 7.72	11.5 19.0	Nil 0.93	Nil Nil	Nil Nil	0.02 0.02	0.012 0.020	— —	— —	— —	
249	Jumo 211	June 1943	Inlet Exhaust	0.43 0.43	0.42 1.02	3.70 2.73	0.009 0.009	0.012 0.013	0.16 9.44	9.24 20.9	Nil 1.06	Nil Nil	Nil Nil	0.10 0.08	0.070 0.050	— —	— —	— —	
204	Jumo 213A1	April, 1944	Inlet Exhaust	0.52 0.46	0.40 1.11	3.06 2.46	0.024 0.008	0.015 0.018	1.07 9.36	9.0 17.4	Nil 1.23	Nil Nil	Trace Nil	0.09 0.08	0.044 0.033	Ti. 0.01 Zr. 0.05 max. Nil 0.05 max.	235/302 215/279	Stem: drilled from head end. Stem: drilled from head end. Head: hollow.	

TABLE I—CONTINUED

Item No.	Type of Engine	Date plane brought down	Type of Valve	Chemical Composition—weight %													Diamond Pyramid Hardness	Constructional Details
				C	Mn	Si	S	P	Mi	Cr	W	Co	Mo	Cu	Al	Other Elements		
135	BMW 801	—	Inlet Exhaust	0.49 0.48	0.55 0.99	2.88 1.38	0.024 0.038	0.024 0.023	Nil 13.2	10.4 15.6	Nil 2.46	Nil Nil	0.26 0.23	Nil 0.22	0.030 0.009	—	282/309 228/272	Solid. Stem: drilled from tappet end. Head: Hollow.
169	BMW 801D2	Aug., 1942	Inlet Exhaust	0.43 0.47	0.37 0.82	3.10 1.43	0.017 0.026	0.011 0.017	0.30 11.9	9.36 15.0	Nil 2.36	Nil Nil	0.05 Nil	0.12 0.08	0.004 0.010	—	—	—
206	BMW 801A2	—	Inlet Exhaust	0.38 0.42	0.43 1.19	3.36 2.25	0.021 0.023	0.018 0.022	0.23 11.8	11.2 18.8	Nil 1.31	Nil Nil	Nil Nil	Nil Nil	0.004 0.016	—	—	—
217	BMW 801A2	Jan., 1943	Inlet Exhaust	0.50 0.41	0.47 0.89	3.04 1.43	0.023 0.015	0.015 0.017	0.16 11.1	8.68 18.3	Nil 2.30	Nil Nil	Nil Nil	0.08 0.08	0.009 0.013	—	—	—
243	BMW 801A	—	Inlet Exhaust	0.43 0.47	0.35 0.77	2.72 1.34	0.020 0.016	0.015 0.018	0.19 13.4	10.7 15.6	Nil 2.42	Nil Nil	0.17 0.17	0.06 0.03	0.022 0.018	—	—	—
258	BMW 801G	May, 1943	Inlet Exhaust	0.51 0.46	0.45 0.84	2.82 2.49	0.010 0.010	0.016 0.014	0.20 9.28	9.1 20.0	Nil 1.88	Nil Nil	Nil 0.10	0.04 0.07	0.004 0.007	—	—	—
269	BMW 801G2	Oct., 1943	Inlet Exhaust	0.49 0.40	0.42 1.01	2.76 2.59	0.022 0.011	0.019 0.019	0.57 8.44	8.64 19.6	Nil 1.06	Nil Trace	0.14 0.11	Trace Nil	0.009 0.013	—	—	—
157	DB 601N	Jan., 1942	Inlet Exhaust	0.54 0.48	0.29 1.26	3.16 2.32	0.011 0.016	0.018 0.015	0.18 9.52	13.4 19.8	Nil 1.46	0.06 0.06	0.06 0.13	0.04 0.02	0.018 0.022	—	274/304 245/302	Stem: drilled from head end. Stem: drilled from tappet end.
163	DB 601A	—	Exhaust I Exhaust II	0.46 0.45	0.52 0.50	1.47 1.53	0.015 0.014	0.014 0.016	13.5 12.8	14.8 15.5	2.27 2.34	Nil Nil	Nil Nil	0.016 0.016	0.026 0.026	—	197/262 179/235	Stem: drilled from head end. Stem: drilled from head end.
137	DB 605 A1	—	Inlet Exhaust	0.46 0.38	0.27 0.94	2.44 2.52	0.013 0.008	0.020 0.022	0.42 8.52	10.5 18.7	Nil 0.99	Nil Nil	Nil Nil	0.04 0.03	0.012 0.026	—	—	—
264	DB 603	Aug., 1943	Inlet Exhaust	0.46 0.49	0.30 0.55	3.08 0.60	0.014 0.019	0.018 0.019	0.18 14.2	8.24 14.5	Nil 2.38	Nil Nil	Nil 0.67	0.17 0.17	0.044 0.044	Tl. Zr. 0.02 0.05 max. Nil 0.05 max.	249/289 207/248	Stem: drilled from head end. Stem: drilled from head end.
295	DB 605	Jan., 1944	Inlet Exhaust	0.50 0.36	0.39 1.18	3.34 3.58	0.011 0.015	0.018 0.027	0.14 7.92	8.68 17.3	Nil 1.23	Nil Nil	Nil Nil	0.09 0.05	0.033 0.039	0.03 0.05 Max. 0.07 0.05 max.	270/290 245/322	Stem: drilled from head end. Stem: drilled from head end.
221	Kinsei 44	—	Exhaust	0.44	0.46	0.59	0.012	0.016	14.1	13.6	2.66	0.32	0.20	0.03	0.044	—	189/199	Stem: drilled from tappet end. Head: hollow.

* Date marked on engine.

Hardness Tests

The hardness values of the valves were normal for their structural condition. Inlet valves were approximately 240/340 HD/10 and the exhaust valves 180/320 HD/10.

Micro Structures

The steels used for the inlet and exhaust valves examined were of a high standard of cleanness except for one BMW 801 valve (Item No. 135) which contained an excessive number of sulphide inclusions.

Inlet Valves. The structures of the inlet valves of DTD.13 B type consisted in all cases of carbide particles in a matrix of ferrite.

Exhaust Valves. The structures of the exhaust valves of both DTD.49B and DTD.282 types consisted of carbides in a matrix of austenite.

Lead Attack

The presence of lead compounds in the scale on the valves indicated the use of leaded fuel and evidence of lead

attack on the valve material was frequently noted. Three exhaust valves examined recently (Item Nos. 264, 295 and 304) have shown that an attempt by the enemy has been made to combat this attack by covering the head by a thin surface layer of chromium metal. This layer of chromium plating was 0.002 in. to 0.004 in. thick and extended over the upper and lower surfaces of the valve head.

Summary

The inlet and exhaust valves examined since the first report suggest that the high standard of quality of workmanship previously noted has been maintained.

The use of a steel equivalent to British DTD.49 B for exhaust valves appears to have been largely discontinued in favour of a steel equivalent to British DTD.282. This possibly indicates the need to conserve nickel and tungsten supplies at the expense of an increased chromium

consumption, which may not cause embarrassment.

An interesting feature of recent exhaust valves was the evidence of an attempt to combat lead attack by coating the upper and lower surfaces of the valve head with a thin plated layer of chromium metal.

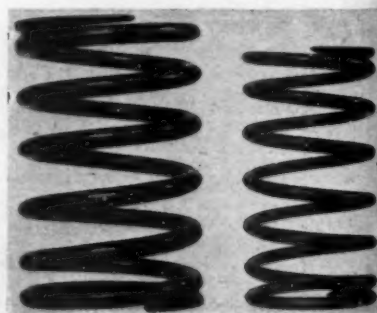


Fig. 1.—Inlet valve springs of Jumo 211 J.1.

Section VII—Valve Springs

SETS of springs from the inlet and exhaust valves of Jumo 211 J1, B.M.W. 801 A1 and B.M.W. 801 D2 engines have been examined, as well as a set of springs from a Japanese Kinsei 44 engine. The sets of springs from the B.M.W. engines comprised outer, middle and inner springs, while the Jumo and Japanese sets included only outer and inner springs. Sets of the springs are illustrated in Figs. 1 to 4, and results of the examination are given in Table I.

Visual Examination

The surfaces of the German springs had been sand blasted, and had then been coated with lacquer in the case of the Jumo springs and with cadmium in the case of the B.M.W. springs. The Japanese springs showed numerous heavy die-marks, and no surface treatment such as sand blasting had been carried out, but the springs received a coating of cadmium.

Dimensions

A key to the dimensions is given in Fig. 5, and the dimensional details of the springs are given in Table 2.

Analysis and Grain Size

The steels had apparently been made in the basic electric arc furnace. The steel used for the springs for the Jumo 211 J1 engine was of the silicon-chromium type previously noted in the case of the Jumo 211 F1 engine, while the other German springs were of the 0.50/0.60% carbon steel type. The Japanese springs were also of carbon steel, but with a higher carbon content of 0.75/0.85%. The inherent grain size of the steels was very variable, being mainly medium to fine.

Magnetic Etch Tests and Macroscopical Examination

Magnetic etch tests and macroscopical examination revealed no evidence of cracks or surface defects in any of the springs. In the case of the springs from the B.M.W. 801 A1 engine, numerous slight die-marks were noted, while the springs from the Kinsei engine showed marked die-marks.

Hardness Tests

The tests reported in Table 1 indicate a fairly uniform hardness in the German springs, equivalent to a

range of tensile strength of 85 to 97 tons per sq. in. in the case of the carbon steel B.M.W. springs, and to a range of 96/105 tons per sq. in. in the silicon-chrome steel Jumo springs. The

Japanese springs showed a marked decrease in hardness towards the surface, but the general hardness corresponded to a tensile strength of approximately 90 tons per sq. in.



Fig. 2.—Valve spring assembly of BWM 801 A.1.

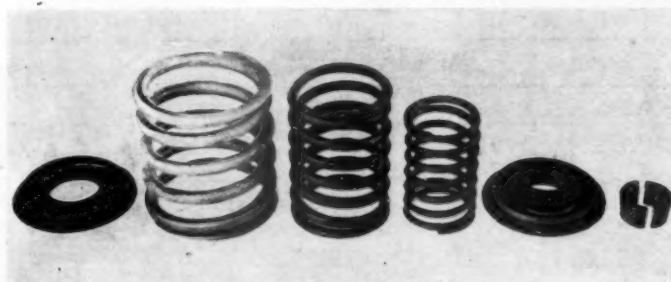


Fig. 3.—Inlet valve springs of BMW 801 A.1.

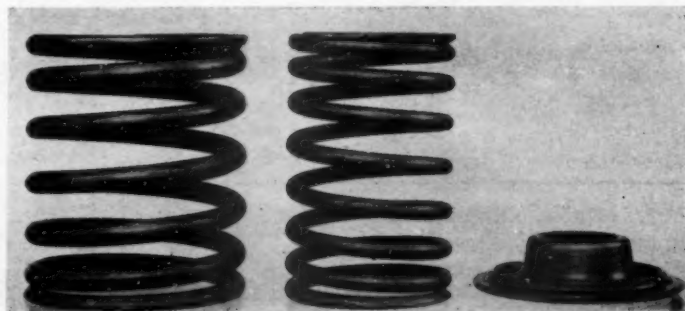


Fig. 4.—Valve springs of Kinsei 44.

Fig. 5.—Dimension calculations. →

Solid height .. = (Total number of coils - $\frac{1}{2}$) d
 No. of active coils = Total No. of coils tip to tip - $1\frac{1}{2}$
 Length of wire .. = $D \times \pi \times$ No. of coils = $D \times \pi \times n$
 Total deflection .. = Free height - solid height
 where d = diameter of wire
 D = mean diameter of coil at the centre of the spring.

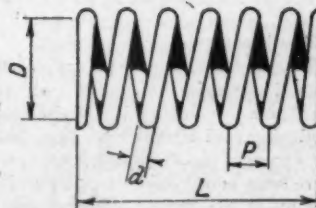


TABLE I. VALVE SPRINGS. CHEMICAL COMPOSITION, HARDNESS VALUES AND RESULTS OF VISUAL EXAMINATION.

Item No.	Type of Engine	C	Si	Mn	S	P	Ni	Cr	Mo	V	Cu	N	Diamond Hardness	McQuaid Ehn grain size	Exterior Examination		Class.
															Coating	Surface finish	
185	Jumo 211 J1																
	Inlet— Outer	0.59	1.26	0.62	0.020	0.011	0.035	0.65	Trace	Nil	—	0.013	451-464	5-6	Dark golden	Sand blasted	Good
	Inner	0.59	1.44	0.76	0.015	0.012	0.095	0.65	Trace	Nil	—	0.014	478-493	4-6	brown lacquer	"	"
	Exhaust— Outer	0.62	1.33	0.65	0.022	0.012	0.09	0.66	Trace	Nil	—	0.013	498-519	5-6	"	"	"
150	Inner	0.63	1.53	0.72	0.020	0.012	0.045	0.65	Trace	Nil	—	0.015	460-509	6-7	"	"	"
	R.M.W. 801 A1																
	Inlet— Outer	0.56	0.20	0.45	0.021	0.005	0.10	0.075	Nil	Nil	0.09	0.005	410-464	2-8	Cadmium plated	"	"
	Middle	0.71	0.205	0.57	0.019	0.007	0.09	0.075	Nil	Nil	0.10	0.0045	422-444	2-8	"	"	"
	Inner	0.69	—	0.60	0.019	0.012	0.055	0.065	Nil	—	0.11	0.0055	426-452	1-6	"	"	"
	Exhaust— Outer	0.70	0.19	0.47	0.019	0.008	0.06	0.065	Nil	Nil	0.08	0.0055	384-424	3-5 (Mainly 4)	"	"	"
	Middle	0.66	0.20	0.61	0.019	0.024	0.05	0.075	Nil	Nil	0.065	0.005	402-429	2-6	"	"	"
	Inner	0.65	—	0.45	0.017	0.004	0.03	0.08	Nil	Nil	0.115	0.005	414-444	2-5 (Mainly 3-4)	"	"	"
	BMW 801 D2																
	Inlet— Outer	0.65	0.20	0.46	0.010	0.025	Nil	0.01	Trace	Nil	—	0.005	421-455	2-5	Cadmium plated	Sand blasted	Good
170	Middle	0.67	0.22	0.52	0.012	0.006	0.025	0.08	Trace	Nil	—	0.0055	446-469	3 5 (Mainly 4-5)	"	"	"
	Inner	0.66	0.22	0.45	0.015	0.008	0.13	0.12	0.045	Nil	—	0.005	426-451	4-6	"	"	"
	Exhaust— Outer	0.63	0.25	0.54	0.011	0.012	0.005	0.12	Trace	Nil	—	0.0055	429-448	3-7 (Mainly fine)	"	"	"
	Middle	0.63	0.20	0.51	0.015	0.007	0.055	0.14	Trace	Nil	—	0.006	437-464	2-7	"	"	"
	Inner	0.67	0.22	0.45	0.014	0.008	0.125	0.13	0.04	Nil	—	0.006	421-455	3-5	"	"	"
	Japanese Kinsei 44																
	Outer	0.83	0.105	0.30	0.008	0.025	Nil	0.025	Nil	Nil	Trace	0.0045	316-400	2-5	"	No surface treatment — showed die marks.	Good
	Inner	0.76	0.235	0.33	0.012	0.021	Nil	0.11	Nil	Nil	Trace	0.005	336-432	1-5	"	"	"

TABLE II. DIMENSIONS OF VALVE SPRINGS.

Item No.	Type of Engine	185				150 and 170						222	
		Jumo 211 J1				BMW 801 A1 and 801 D2.						Kinsei 44	
		Inlet		Exhaust		Inlet			Exhaust			Outer	Inner
		Outer	Inner	Outer	Inner	Outer	Middle	Inner	Outer	Middle	Inner	Outer	Inner
Diameter of wire: in. = d		0.187	0.135	0.186	0.135	0.249	0.193	0.137	0.249	0.195	0.137	0.213	0.163
Number of coils = n		7	7½	7	7½	5½	7½	8	5½	7½	8	7	8½
Number of active coils		5½	6½	5½	6½	3½	5½	6½	3½	5½	6½	5½	7
Diameter of coils, in. —													
External		1.788	1.325	1.788	1.322	1.325	1.759	1.265	2.319	1.750	1.270	2.118	1.567
Internal		1.414	1.055	1.416	1.062	1.827	1.353	0.991	1.821	1.360	0.996	1.692	1.261
Mean = D		1.601	1.188	1.602	1.195	2.076	1.546	1.128	2.070	1.555	1.133	1.905	1.434
Free height, in. = L		2.791	2.558	2.787	2.488	2.492	2.578	2.089	2.468	2.560	2.033	2.517	2.321
Solid height		1.251	0.979	1.209	0.979	1.245	1.013	0.822	1.245	1.024	0.822	1.385	1.304
Total deflection		1.576	1.579	1.578	1.509	1.247	1.565	1.267	1.223	1.536	1.211	1.132	1.217
Pitch of coils = P		0.547	0.448	0.549	0.453	0.571	0.386	0.316	0.567	0.384	0.314	0.524	0.429
Length of wire, in. = l		35.2	28.9	33.2	29.1	35.9	36.4	28.3	35.7	36.6	28.5	41.9	38.1
Hand of spiral		Right	Left	Right	Left	Right	Left	Right	Right	Left	Right	Right	Left
Weight of springs, oz.		4.00	1.72	4.00	1.72	7.31	4.59	1.84	7.34	4.66	1.87	6.25	3.39

Microscopical Examination

All the steels were of a satisfactory standard of cleanness, the small quantity of inclusions consisting of finely dispersed sulphides and silicates, except in the silicon-chromium Jumo springs, where small angular particles of titanium nitride were present.

None of the German springs showed any decarburisation, and all the structures confirmed satisfactory hardening and tempering. The structures were of the fine sorbitic type, and there was some evidence of banding in some of the springs. Typical microstructures are illustrated in Figs. 6 and 7.

The Japanese springs showed marked decarburisation to a maximum depth of 0.005 in., while the general

TABLE III.

	Item No. 150			Item No. 222
	Top Seating	Bottom Seating	Split Bushes	
Carbon	0.495	0.495	0.38	0.23
Silicon	0.325	0.29	—	0.27
Manganese	0.58	0.70	0.68	0.41
Sulphur	0.013	0.012	—	0.024
Phosphorus	0.010	0.010	—	0.019
Nickel	0.04	0.05	—	3.16
Chromium	1.10	1.10	2.33	1.28
Molybdenum	Trace	Trace	0.135	0.61
Vanadium	0.22	0.20	0.15	8.9
Copper	—	—	—	0.16
Nitrogen	—	—	—	0.007
McQuaid-Ehn Grain Size	7-8	5-7	—	4-6 (mainly 5)
Coating	Cadmium	Cadmium	Cadmium	Cadmium
Heat Treatment	Hardened and tempered	Hardened and tempered	Hardened and tempered and nitrided. Case depth 0.013 in.	Hardened and tempered
Diamond Hardness	375	375	Case 710 Core 294	342

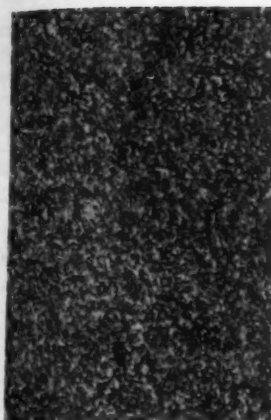


Fig. 6.—Structure of valve spring of Jumo 211 J.I. $\times 300$

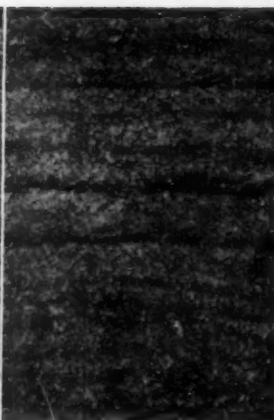


Fig. 7.—Structure of valve spring of BMW 801 D.2. $\times 300$



Fig. 8.—Structure of surface of valve spring of Kinsel 44. $\times 300$

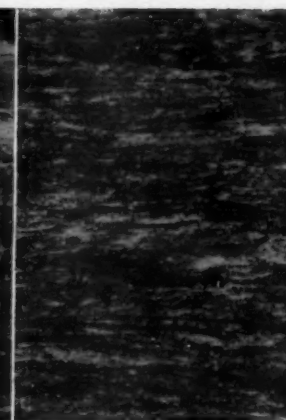


Fig. 9.—Typical structure of valve spring of Kinsel 44. $\times 300$

structures (which consisted of dense sorbite with occasional small areas of ferrite), indicated the spring wire had been satisfactorily patented and drawn. Figs. 8 and 9 are typical of the structure at the surface and the general structure of these springs. The

quality of these Japanese springs was generally inferior to equivalent British and German valve springs.

Spring Seatings

The valve spring seatings and split bushes from the B.M.W. 801/A1

engine (Item No. 150) shown in Figs. 2 and 3, and the seating from the Kinsel 44 engine (Item No. 222) shown in Fig. 4, were also examined. Table 3 gives the results of this examination.

To be continued

Reviews of Current Literature

Time Study and Rate Fixing

THIS book is the first publication of the Institute of Economic Engineering, formed in 1941, as the official organisation of estimators, planning and time study engineers and rate-fixers in industry. It is based upon eighteen lectures, under the title, "The Determination of Working Times in Engineering Works," given by Professor F. L. Meyenberg, M.I.Mech.E., M.I.Ec.E., in 1943. Points arising from the discussions following each lecture have been used and, it is important to note that a Committee was selected by the Council of the Institute, who carefully scrutinised the original manuscript to ensure, as far as possible, that information given in the book provided a basis for use in industrial concerns in this country.

A great deal of literature on time study has been published since F. W. Taylor published his fundamental considerations on the subject over forty years ago. At that time everything seemed to be so simple that few appreciated the need for the thoroughness with which he treated the subject. The complexity of the method he recommended was not then apparent to the average production engineer, but the extensive literature now available on this problem has emphasised its complexity and has indicated the great amount of care necessary to apply time study methods successfully.

The need for time studies in industry is not new; in the manufacture of articles or components it is necessary to estimate and evaluate the working time likely to be involved before a price can be quoted. While the application of time studies in earlier days was simple, the complexities of modern industry greatly increase the difficulties in estimating for any given work. Attention is particularly drawn to the close connection between

the technical, psychological and economic aspects in time study work, from which follows the fact that the solution of the problem in a particular case must always be developed according to the special circumstances and conditions of the case in question. In other words, there is no one method or system which is applicable to every case.

It is modestly claimed that this book provides an introduction into the fundamentals and principles of time study work, illustrated as far as possible by examples taken from actual practice. It also provides an introduction into the method of application of these principles and, especially, a description of the spirit in which time study work should be approached in practice. Time studies should be regarded as the best means of creating an atmosphere of co-operation throughout the works, and the time study engineer as the best mediator between the seemingly conflicting interests of management, staff and workers. He can play this role only if he tackles his problems in a way as fair to both sides as humanly possible. This book will help him in this task as far as any publication can do, while he himself must do his best to carry out the ideas explained into action, with due consideration of the working conditions of the case in question. Particular attention is directed to concluding pages in which is briefly discussed the education of the time study engineer and his position in relation to the works organisation.

This book is authoritative and, rightly used, it should help to create the spirit of co-operation so urgently needed in post-war industry.

Based on Lectures given by Professor F. L. Meyenberg, M.I.Mech.E., M.I.Ec.E.; edited by the Institute of Economic Engineering. Demy 8vo. 225 pp., with 63 figures. Published by Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. Price 20s. net.

The Equilibrium Diagram of the Aluminium-Magnesium System

THIS is the latest addition to the Institute of Metals Annotated Equilibrium Diagram Series. It contains (a) the diagram reproduced on a generous scale and based on what is regarded as the most reliable work in each phase field, (b) a table giving all important data connected with the diagram, (c) a number of critical notes, and (d) a list of references.

Nos. 1 to 4 of the series are still available, price 6d. each, post free. They deal respectively with the aluminium-zinc, copper-tin, copper-zinc and copper-aluminium systems.

By G. V. Raynor, M.A., D.Phil. (Institute of Metals Annotated Equilibrium Diagram Series, No. 5). 11½ × 8½ in. Pp. 6 with 1 fig. 1945. London: The Institute of Metals, 4, Grosvenor Gardens, S.W.1. (6d., post free).

Industrial Electric Furnaces and Appliances, Vol. 1

HEAT has an important influence upon the quality and cost of nearly all manufactured products and since early days much attention has been given to methods of application and of control, but it is only during comparatively recent years that real progress has been made. By comparison with inefficient methods of applying heat in earlier days, there is, to-day, a better understanding of the underlying principles and of the means of controlling the many factors that affect the heating operations. This is true, whatever the form of heat energy used, but, in determining the form in which heat is applied, it is necessary to bear in mind that which is sought—the manufacture of a quality product at low cost.

Fuel-fired equipment for industrial heating has been used for centuries, whereas the use of electric equipment for this purpose is much more recent; indeed, only in the past twenty-five years has there been rapid growth in the application of electric heating. But much remains to be done before industrial electric furnaces in general can be regarded as precision tools and this book can certainly be regarded as a useful contribution to this end.

It is important, as the author points out, that the designer and user of industrial heating equipment should think more in terms of uniform heat transfer to and from the product to be heated—not merely in comparative terms of electricity or fuels or of temperature control. The economic value of a heating operation should be expressed in terms of relative uniform quality and over-all cost of the ultimate product. It is noteworthy, therefore, that the author places special emphasis upon the thermal aspects of furnace design and operation, especially in relation to uniformity of the product to be heated; the frequently unrecognised interrelations of thermal and electrical factors associated with such equipment is also stressed.

The book is planned in two volumes. In a general chapter in the present volume the author deals with the thermal, electric and economic principles applying to all types of furnaces and appliances. A second chapter discusses arc furnaces and electrode melting furnaces; emphasis is placed on steel melting furnaces. In a separate section the special design of ferro-alloy furnaces is considered. The second volume contemplated will deal with induction, capacitance, and resistance heating.

This book will not only be invaluable to furnace

design engineers, but will be helpful to furnace operators who desire to improve their knowledge of the important production tool they use; it will also be useful to power engineers, concerned with expansion of the electric heating field, and will tend to develop in technical and production personnel a better understanding of the economic importance of industrial heating. It is admirably prepared and illustrated, and includes very useful design formulae.

By Victor Paschkis, M.E., E.E., D.Sc. Med. 8vo. Pp. 232, with 158 figures. 1945. Published by Interscience Publishers, Inc., New York, N.Y., U.S.A. Price \$4.90.

High Duty Cast Iron

THIS small book has been prepared especially for engineers and designers with the object of bringing to their notice useful information relating to high duty cast iron. It directs attention to the factors that contribute to the successful functioning of the modern foundry, designed and equipped to produce castings that are sound, clean, accurate and to specification. These requirements are discussed and the need for control, as an important governing factor, is emphasised, especially for a foundry specialising in the production of high duty acicular iron castings.

Cast iron possessing the acicular structure is produced by the addition of alloys to what would otherwise be a high duty cast iron possessing a pearlitic structure. Its properties are of an outstanding character and it is included in the "Acculite" high duty cast irons which are a product of Messrs. Sykes and Harrison Ltd. This company's technique of manufacture is discussed and useful information is given on the material and castings produced that will be of value to engineers and designers.

Published by Sykes & Harrison Ltd., High Duty Iron Founders, Piercy Street, Manchester, 4.

BS/STA 7 Services Schedule of Non-Ferrous Metals and Alloys

Group 6. Aluminium and its Alloys

COPIES of the above group of specifications are now available. The group comprises an up-to-date rationalised schedule of aluminium and aluminium alloys systematically arranged according to the general plan of the BS/STA 7 Services Schedule of Non-Ferrous Metals and Alloys. A number of alloys not previously standardised are included. It is divided into three sections, the first covering aluminium, the second aluminium casting alloys and the third wrought aluminium alloys. The first section includes specifications for aluminium of four different degrees of purity, the second contains fifteen specifications for casting alloys, divided under the following headings: Casting alloys for general purposes; casting alloys for particular applications; and piston alloys. The third section contains eighteen specifications for wrought aluminium alloys, divided under the headings: Alloys not heat treated; and heat treated alloys.

At the present time, when increasing emphasis is being given to the advantages of aluminium and its alloys for engineering equipment in general, coincident with the increased availability of these materials, this schedule of specifications should be of exceptional value. It is issued for the Ministry of Supply by the British Standards Institution, 28, Victoria Street, London, S.W.1. Price 1/- post free.

The Coinage Metals in Antiquity

Part V.*—Aegean and Offshoot Cultures; Cloisonné

By Douglas Rennie Hudson, B.Sc., Ph.D.

(University of Leeds).

"It was supple without being effeminate, and while it had the proper colour of bronze, it looked bright and fresh; and though quite wanting in actual motion, it was quite ready to show motion; for though fixed firmly on a pedestal, it deceived one into thinking that it had the power to fly."

CALLISTRATUS: On the statue of Eros.

ABSTRACT.

In an attempt to indicate the currents of diffusion through Europe from the Eastern Mediterranean, individual metal artefacts are cited under the heads:—

1. CRUX CUM SEPTEM MYSTERIIS JESU CHRISTI.
2. THE TRAPRAIN SILVER HOARD.
3. DUKE TASSILO'S CHALICE AT KREMSMUNSTER.
4. THE CUP OF ST. AGNES' MARTYRDOM.
5. ETRURIA.—Etruscan Metallurgy; Etruscan Tin and the Discovery of Bronze Making; Metal-liferous Mining, Tin and Iron (with Zinc and Lead), Sulphide Copper Ore.
6. SARDINIA.—Copper and Bronze.
7. THE METALS IN ALCHEMY.

Etruria is noted for fine yellow pottery, with line decoration in brown and red, simulating that of Mykenae and perhaps of allied origin. About the fifth century B.C. it was famous for bronze work—candelabras, chased armour and mirrors, which enjoyed high standing in Greece and Rome. With the Roman conquest their skill was re-incarnated in the magnificent bronze statuary of Rome, of which so much survives. As in Cornwall, copper and tin ores occur in close association and ancient lode workings were extensive, so that Etruria has been proposed as the *locus* for the invention of bronze. By the Christian era, Rome became famous as a patron of fine silver work, probably stimulated by rising production from Laurion and Andalusia. Process work in Sardinia, in which Carthaginian and Phoenician influence was strong, far exceeded artistic attainment.

16. CRUX CUM SEPTEM MYSTERIIS JESU CHRISTI.

IF the Early Christian Church extended little sympathy to the enquiring and questing mind of the primitive scientist or natural philosopher intolerant of absurd dogma, her patronage of the craftsman was both generous and consistent, provided he confine his attention to sacred subjects *ad maiorem gloriam Dei*. The splendid enamelled cross from the Lateran Chapel *Sancta Sanctorum* (Fig. 45) is now preserved in the Vatican Museum. It has been carefully studied by LAUER and by FR. GRISAR who respectively assign it to circa 600, and 6-7th century A.D. It weighs 1247 grammes (40.1 oz. troy) and is reputed to be of gold, though the possibility of plated bronze or silver has never been investigated. An identification with the cross of Pope Symmachus (498-514) or a renovation of this, seems doubtful; according to *liber pontificalis—et crucem ex auro cum gemmis, ubi inclaudit lignum dominicum, ipsa cruz pens. lib. X* (say 3275 grammes or 105.3 oz. troy).

The brilliance of the colouring and fineness of execution in this cross are obvious on mere inspection, even to the layman. In style it is Roman, with distinct Byzantine and Syrian influence.

The front panels of the cross show seven scenes from the youth of Our Lord. On the vertical sides is an

inscription in brick red enamel on a glowing emerald background—

PE TO[QUAES] [OQUE] QUOD O A[LMA] D[O]MINA
[ET R]EGINA[MUNDI]H[OC] HO[NORABILE]
O[FFERRE]A[NIMO] T[OTO] EPISCOP[US]T[UUS]
ME[RE]AR TI[B]I P[AS]CHALIS [VE]XILLUM

CRUCIS

Interpretation has given considerable difficulty, in regard to the starting point, the order of the words (which in Latin generally is unimportant) and the position in which the cross should be held while they are read. The above rather free adaptation by SCAGLIA is rendered—

O high lady and queen of the world, I beg and beseech that Paschalis thy bishop may be worthy to lay before thee this honorable standard of the cross.

Pope Paschalis I ruled 817-824, Paschalis II 1099-1118.

17. THE TRAPRAIN SILVER HOARD

This fine collection of thieves' loot, exceeding 770 oz. troy of silver, was unearthed in the 350 ft. stump twenty miles east of Edinburgh called Traprain Law, by CURLE in 1919. By coins (Roman 4th century) within the hoard, and two others above it, one may date it with unusual certainty at the beginning of the 5th century

* Continued from October, 1945, p. 280.

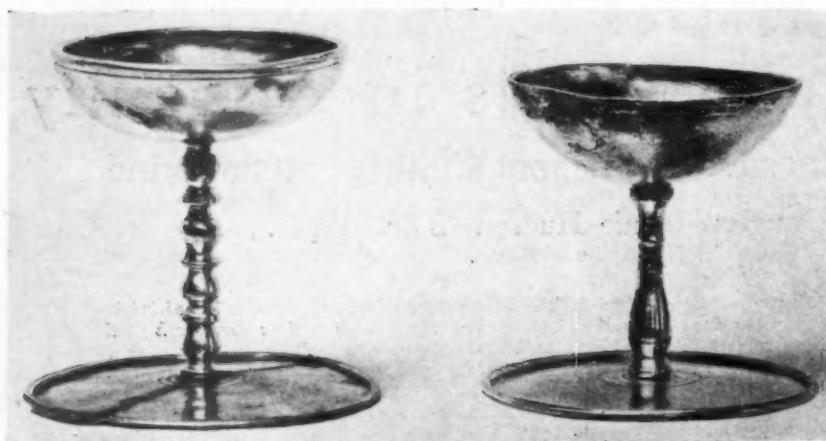


Fig. 48.—Silver goblets from THE TRAPRAIN SILVER HOARD, probably Roman household plate.—National Museum of Antiquities, Edinburgh.

A.D. Amongst the 160 pieces were 10 flagons or flasks, 50 bowls, 22 dishes and 9 spoons, of widely divergent provenance. Nearly all had been damaged, some were even beaten into compact packets ready for the pot. Christian, Teutonic, and Alexandrian work has been identified, with inscriptions in Latin and Greek. Some show amalgam gilding. Despite severe hacking and beating, the objects are of great interest from the point of view of craftsmanship. Most of the parallels have been drawn from styles domesticated in southern Europe and the eastern Mediterranean "there is little room for doubt that the booty was obtained in Gaul," perhaps after the sack of Rome by the Visigoths in A.D. 401. Thus, unfortunately, its diagnostic value is nil.

Fig. 48 shows the fine lines of two silver goblets about 4 and 3½ inches high. The bowls are gilt internally and riveted to the stems without trace of soldering. They are considered to be Roman household goods rather than sacred chalices; PLINY (*Natural History*, 33) commented on the profuse use of silver, mainly of Spanish origin, during the 1st century, A.D.

A large shallow heavy dish, 12 inches in diameter, with alternate plain flutings and sectors with chased parallel palmette patterns, is shown in Fig. 49. In the circular medallion a nymph is shown riding on a sea lion, while waving a diaphanous veil over her head. The outline engraving is enriched with punched dots and in treatment the subject is reminiscent of Iranian or Phoenician work. Three hooks are attached outside the rim, a pair and a single hook at opposite ends of a diameter, by soft solder. The consequent suggestion that this vessel may have served as a "hanging-bowl," very popular for decoration for church arcades in Anglo-Saxon periods, is unlikely. Such an arrangement of hooks would give very unstable suspension, and in view of the highly ornamented interior and plain exterior it seems unlikely, to say the least, that it was designed for this purpose. Bending outward of the hooks is said to be a typically Roman treatment so that the dish may possibly be an adaptation of an original of other provenance.

Compare with the following passage from PHILOSTRATUS THE SOPHIST—"She holds over her head against the wind a light scarf of sea-purple to provide a shade for herself

and a sail for her chariot, and from it a kind of radiance falls upon her forehead and her head, though no whit more charming than the bloom upon her cheek; her hair is not tossed by the breeze, for it is so moist as to be proof against the wind. And lo, her right elbow is extended and her white forearm bent back, while she rests her fingers on her delicate shoulder, and her arms are gently rounded and her breasts stand out, nor is beauty lacking in her thigh. Her foot, with the graceful part above it, is painted as on the sea, lad, and it touches

the water lightly, as though a rudder guiding her chariot. Her eyes are wonderful, for they have a sort of distant gaze that extends as far as the ocean itself."

18. DUKE TASSILO'S CHALICE AT KREMSMÜNSTER

This fine example of eighth century metal work has been described frequently. From the inscription in gilded letters on a silver strip round the base

Fig. 49.—Scalloped silver dish from THE TRAPRAIN SILVER HOARD, possibly Phoenician or decadent Iranian. National Museum of Antiquities, Edinburgh.





Fig. 50.—The gold cup, exhibited to the Society of Antiquaries of London in 1905 by the Duke of Portland, was attributed by READ to late 17th century, probably South German work from the hand of a leading craftsman of Augsбург or Nuremberg. The thin shell bowl is enamelled and jewelled, chasing and engraving is very highly finished; the figures show unusual vigour, perfect modelling and a well developed artistic sense. At the summit Eros is depicted astride Pan, and the stem is built up of a wonderfully depicted pair of lovers embracing. The lozenge foot consists of enamelled scrolls alternating with jewelled bands.

TASSILO DVX FORTIS + LIVTPIRG VIRGA
REGALIS +

we may confidently date it as a little before A.D. 788 when Duke Tassilo of Bavaria was deposed. Probably about the beginning of the ninth century it was presented to Kremsmünster monastery where it has remained ever since as a precious treasure willingly shown to visitors on request. The bowl is attached to the foot and boss by a joint concealed by a ring of 25 beads. There has been some conflict of opinion as to whether the integral parts are wrought work or castings, though



Fig. 52.—Bronze statue of a young girl. Munich Antiquarium.

inspection of the ornament would certainly suggest the former.

On the bowl exterior are five medallions depicting Our Lord and the Four Evangelists on riveted silver plates,

engraved and filled with niello. Tarnishing of the silver has much reduced the contrast (*ibid*, Fig. 14). At the apices of the diamond panels on the boss a few green and blue pastes remain. Much controversy has centered round the decoration. The enthusiasm with which it was originally attributed to "Irish" workmanship is now substantially abandoned. Certainly it shows some distinct *Scotic* patterns; e.g., the knot and zoomorphic decoration are reminiscent of stone crosses, and the animals of the Tara Brooch and the Book of Kells. However ALLEN and MACALISTER would regard the

Keltic beast as three toed while the Teutonic is twin toed, as on this chalice (?). Though rather slender the point is worth consideration. Palmettes and scrolling are distinctly Carlovignian while some of the treatment is massive and definitely Kerbschnitt. Penetration treatment is Viking.

Any conclusion from these divergent pointers will be tentative at best. Probably we are not too rash in attributing the artefact to an itinerant Irish monk with experience of monastic shops in many countries, wide in vision and bold in adaptation of traditional treatment to indigenous patterns from many sources, or even to a native pupil working under tutelage none too strictly exercised. Composite workmanship is possible though in the author's view unlikely. It has been suggested that the chalice was made in Salzburg.

19. THE CUP OF ST. AGNES' MARTYRDOM

"... il faut reconnaître que jusqu' ici on peut considérer cette coupe comme un témoin unique du luxe des souverains français."—MOLINIER.

Only rarely can a jewel as fine as the Gold Cup of St. Agnes' show a history authenticated over six centuries. It was probably made for the Duc de Berri, brother of Charles V, by one of his staff artificers, possibly *Hennequin de Vivier* or *Jacquemart de Hesdin*, after the middle of the 14th century. By great good fortune its history can be traced in inventories and records in remarkable detail—

1. INVENTAIRE DES MEUBLES ET JOYAUX DU ROY CHARLES VI, 1391 AND 1399. Bibliothèque Nationale mss. 21445, f.16; 21446, f.45v.

Item un hanap dor a tout son couvescle esmaillé bien et richement par dehors de la vie Madame Sainte Agnes . . . A donna led' hanap et couvescle au Roy monseig' De berry au voyage de Touraine lan 91 et poise led' pie troise marcz cinq onces et demye.

2. JOHN, DUKE OF BEDFORD, REGENT OF FRANCE. 30 JUNE, 1434. (Exch. K. Remembr. Inventories $\frac{1}{2}$).

Item. Vne coupe d'or couvert, esmaillée de la vie Seinte Suzanne, garnie de iiij, saphirs, deux balais et xiiij perles; et es cour onnes de couvercle de la pie, de lxj perles; pesant ix m[arcs]. j. o[nce]. x. e[sterlins].

3. JOHN, DUKE OF BEDFORD, [after his death, no date].

First a coupe of gold ennamailed w' ymagerie garnished w' stones & ples poisons togeders vj lb. j. once di [73½ oz. troy].

4. HENRY VI, 1449.

Item unum ciphum auri coopertum et esmaelitum cum diversis imaginibus et garnizatum cum ij bales [balas rubies] iiij saphiris et lxxvj perulis, ponderis lxxiiij unc. iiij quart.

5. HENRY VIII, 1521.

12 Hen. VIII. Duke of Portland—Welbeck.

Item a cuppe of golde enamelled with ymagerie, the knop a crowne imperiall and aboute the border of the cover and foote a crowne garnished with 62 garnishing perles poyz 79 oz.

The addition to the weight is attributable to the insertion in the stem and replacement of the crowne imperiall for the original knop.

6. 16 QUEEN ELIZABETH, 1574.

British Museum: Stow mss. 555, f.9.

Item a cup of golde with imagerie the knop a Crowne Imperiall and about the border of the cover and the foote a crowne garnished with lxj garnishing perles ponderans lxxix. oz.

This is repeated with verbal changes, in the 1596 inventory.

The cup was given as a present to Juan Fernandez de Velasco Duke of Frias and Constable of Castile and Leon when an envoy of the King of Spain to arrange a peace treaty with James I of England and Wales and VI of Scotland. It was transferred by him with other rich gifts of reliquaries, relics and crosses, to the Convent of St. Clara in Medina de Pompa on 29 May, 1610, under strict guarantee of inalienability.

In 1883 a Spanish priest Fr. Campo, on behalf of the now impoverished nunnery, brought the cup to Paris for sale but failed to find a buyer—the low price and excellent condition (Fig. 46) arousing suspicion that it was counterfeit. When he was on the point of leaving, Baron Pichon, having satisfied himself regarding its authenticity by historical investigation and correlation with the stem inscription, bought it after some haggling for about £100 above the bullion value, say £450 (gold) in all. Later he asked the wealthy and generous antiquary Franks the sum of 500,000 francs, say £20,000 (gold), for the cup, which was eventually bought in 1891 by Wertheimers for £8,000. This firm of Jewish financiers agreed to re-sell to the British Museum without profit, the senior partner generously contributing £500. The inscription reads—"GAZAE SACRAE EX ANGLIA RELIQUAS PACIS INTER REGES FACTAE MONUMENTUM, CRATERA AURO SOLIDUM, JOAN. VELASQ. COMESTAB. INDE R. B. G. REDIIENS XPO PACIFICATORI D.D. in italic capitals filled with black enamel, a laurel in translucent green being inserted to fill the vacant space.

The gold is almost pure but the stem portion with riveted Tudor roses in relief, is of different colour. Insertion of this cylinder, and replacement of the *Crowne Imperiall* for the original finial, attributable without doubt to Henry VIII, is poor tribute to Welsh artistic taste of the time. Fig. 47 shows the original form, as conjectured by READ. In the 14th century it was even more imposing standing on a foot of gold in the fashion of a tripod, and has in the middle of the tripod an image of *Our Lady in a sun of clear red, and the three feet of the said tripod are formed of three flying serpents.*

Enamelling.—Transparent colours used are luminous crimson, sapphire blue (not very well preserved), emerald green, a neutral bluish grey, brownish black, yellow for hair. A colourless enamel through which the underlying engraved gold is visible, is used for flesh tints. The craftsmanship is very fine and delicate—e.g. the joining of the two constituent plates of the bowl and lid by hammering at the rim without damaging the enamels; treatment is careful yet bold and free from convention. Analogies with the Flemish school (e.g. J. van Eyck) have been suggested, the style is said to resemble certain *Bibliothèque Nationale* mss. (nos. latins 919 and 18014) which may also have belonged to de Berri, but analogies with other contemporary French art are not easy to detect. The Tudor roses are enamelled red and white with green points, and below them on the

stem are the evangelists' symbols with their names on scrolls, very beautifully executed (Figs. 45 and 46).

20. ETRURIA

"Am wenigsten glücklich ist die etruskische Kunst dort, wo sie von klassischer griechischer Kunst abhängt ist."—RODENWALDT.

The early culture of the Italian peninsula is Etruscan or at least derivative from it. The origin of this people is highly controversial. A northern habitat in the Rhaetian Alps was formerly suggested, but is now generally abandoned and invasion from Lydia considered more probable. But it is possible that the Etruscans developed in the country from a primitive *Ur Volk*. Their pottery has been studied in detail, vases of yellow clay, with line decoration in brown or dark red, reminiscent of Mykenaeen products, are widely distributed in Mediterranean countries. Tombs of massive stone blocks resemble those of the Aegean and Helladic civilisations. A date of 1050 B.C., preserved in their tradition as that of their settlement in Tuscany, is certainly much too late.

According to POLYBIUS (2, 17) the Etruscans had twelve cities in the Campania, each ruled by a priest-kinglet, as in Sumer; in 524 B.C. they prepared a great expedition against Cumæ. But in the struggle for commercial domination Etruria was unable to withstand the Latin-Hellenic combination, and with the victory at Cumæ the triumphal progress of Rome, culminating in the *Imperium* and conquest of remote lands, began.

Relations with Carthage, on the other hand, were consistently good. Being inherently peaceful the Etruscans used mercenaries, suffering defeats by Rome from Veii (396) to the Vandimonia Lake in 283 B.C.

A pupil's copy book in the form of an ivory tablet with the Etruscan alphabet engraved on the edge, has been found at Marsiliana in a tomb. The letters resemble archaic Greek, or Phœnician. The gold fibula from Praeneste, inscribed MANIOS MED VHEVHAKED NUMASIOI (*Manius made me for Numasius*) written right to left, is of great interest as the oldest existing form of Latin, and has been published frequently. See also Fig. 44.

Etruscan Metallurgy

Possibly the Etruscans formed only an "upper ten" and not a widely distributed cultured entity in Italy. They were capable mariners, rich and industrious; in one grave in Vetulonia no less than 9lb. of amber, which must have been obtained from the Baltic in trade or barter, was recovered. In masonry construction and metal extraction they were skilled, and very competent in bronze work; the very name bronze comes from the famous mirrors of Brindisi cast in what subsequently came to be known as *speculum metal*—*speculi Brundisini*. In Attica, Etruscan bronze was a house-

hold word in the fifth century B.C. For armour and metal fittings in general their chased plates of bronze were unsurpassed throughout the then extent of the world; they attained something like a monopoly of *repoussé* work until the alloy was eventually displaced when iron extraction became more widespread. This, too, they undertook on the island of Elba. By Homer's time both metals were in use, bronze is mentioned 320 times in the *Iliad* and iron 23 times, according to SEYMOUR.

On account of the massiveness of their tombs, these are rarely contemporary with the funeral furniture found in them, nevertheless it seems probable that gold and silver were more plentiful than bronze in earlier



Fig. 51.—Bronze vessels and ceramic tripod hearth found in a tomb at Zafer Papoura, in Crete.—After Evans.

years, becoming rarer as bronze became widely distributed. In founding they were competent both in technique and style, and when their culture became absorbed in the Roman, this fell heir to their skill. (See also Fig. 52). The famous Etruscan bronze statuettes and portrait heads are reflected in the bronzes of Rome which show fine vigour and real skill in casting. In earlier days Etruscan bronze candelabras were highly prized in the Eastern Mediterranean.

In these circumstances it is not surprising that metal artefacts have been discovered in quantity throughout the peninsula—daggers, leaf swords, *bipennae*, statuettes. The copper has usually small percentages of alloying elements, probably these are process impurities and not modifiers. In addition, real *modified* coppers, low and medium bronzes and leaded bronze have been reported on assay, but there has been much confusion between bronze and copper, assessed only by appearance of the patina, without analysis or even a qualitative test.

Etruscan Tin and the Discovery of Bronze Making ?

Before the Christian era, tin for bronze manufacture exercised as great a pull as any *bonanza* in Klondyke or California or Transvaal in the last century. From a distribution chart of copper and bronze objects re-

covered in France it has been made possible to show how penetration occurred from the Phokian settlement at Marseilles to Cornwall via the Rhone Valley and Brittany. It is reasonable enough to attribute this to overland routing after Etruscan tin was exhausted and before Phoenicians had developed the sea lane through Gibraltar Straits, which later became so well established.

The Tuscan chain is widely and variedly mineralised, though distribution is adventitious. This fact is of great interest in assessing the possible sources of the tin imported to the Eastern Mediterranean for bronze synthesis, well before 1500 B.C., in Cyprus and Egypt. Long before the Phoenicians penetrated to Cornwall, their predecessors brought back tin from nearer fields, probably Etruria and northern Spain in turn. Mosso would go so far as to attribute the invention of bronze to this region—"In the mines of Cento Camerelle, near Campiglia Marittima, in those of Temperino and of Monte Calvi, the chambers connected by little galleries by means of which the metal was extracted are still to be seen. A bronze pick and a few scarabs found at the bottom of a pit attest the remote antiquity of these mines. The stratum of carbonate of lime deposited by the infiltration of water in the walls is of considerable thickness, showing that these mines were abandoned a very long time ago. That the ancients extracted tin and not iron from these mines of Temperino is proved by the fact that the miners left intact too much good iron-stone." Copper was won in the mine of Montieri (Latin *mons aeris* = bronze mountain). "Here we can see how the discovery of bronze was due to chance, for nature has placed together tin and copper in the bowels of the earth, and it must have been discovered by accident that by mixing the two minerals a firmer and more elastic metal of yellowish colour was obtained, better adapted for the manufacture of weapons and cutting instruments.

The hypothesis is at least plausible in itself; Gowland's experimental runs with 15 lb. of 30% malachite, 10 lb. of 20% cassiterite, with 7½ lb. limestone as flux and 10 lb. charcoal fuel, blown through a 1 in. pipe, and smelted in a hole dug in the ground, produced a 22% bronze. Moreover, the assumption that the discovery was carried eastwards to be used in the synthesis of bronze in Cyprus and Egypt pre-1500 B.C., of which we have satisfactory evidence, is at least consonant with the known brisk marine trade in the Eastern Mediterranean before 2000 B.C. As to whether it is correct, the author finds it difficult to express any opinion from the limited archaeological corpus so far available.

Metaliferous Mining

Tin and Iron (with Zinc and Lead).—The mine manager, CORTESE, reported: "At Mount Rombolo I have been let down by ropes to a depth of 70 metres, in order to inspect some large irregular empty spaces where an ore containing lead mixed with zinc seems to have been mined for. At Spinosa, too, I went down into similar places, resembling spiral galleries in vast empty spaces, but I could not make out what had been dug out there. At Monte Valerio all the tin ore to a depth of 35 metres had been worked out. The mines had been penetrated by degrees from the level, leaving only the narrow veins and the poor ore. Amongst the rubbish we found a rich ore containing about 40% tin, more or less, which they possibly did not know how to treat, and also much stanniferous iron-stone, containing from 1% to 10% of tin." In 1876 Blanchard reported

cassiterite in Campiglia Marittima, and mining began forthwith with a yield of 21 and 73 tons from two neighbouring workings in the first year, in 1910 it was still active.

Sulphide Copper Ore.—In 1910 Mosso reported: "Even at the present day these metals (copper and tin) are extracted from the mines of Tuscany in five different localities, in spite of the competition of America and the rich mines in various parts of the world which have put on the market extraordinary quantities of copper and tin. To give an idea of the potentialities of these deposits I record the fact that the mines of Montecatini produce about a hundred tons of metallic copper a year, and an English company extracted 55,000 tons (*sic*) of metallic copper at Campiglia Marittima in 1904." More recently the great Montecatini combine has taken a prominent part in production of aluminium and silicon/aluminium alloys, especially with magnesium, by use of hydro-electric power from the northern ranges—Italy's "white coal."

21. SARDINIA

Sardinia's importance as a deposit of metalliferous ores has been appreciated for nearly three millennia. Human settlement took place in the late neolithic, according to Mediterranean tradition it was invaded from Africa (PAUSANIAS, *Description of Greece*, 10, 17). As in Cyprus, accomplished process work far surpassed artistic attainment in metals.

French *savants* almost unanimously identify Egyptian mercenary Shardina with Sardinians, but other prehistorians are dissentient. About 1200–1090 these marines were extensively used in imperialistic expansion, especially sea-fighting; in many engravings and pictures dating from Rhampsinitos (Rameses III) they are depicted with short jackets, horned helmets, and leaf swords so long as to be unwieldy.

In the course of westward exploration the advantages of Sardinia's central position in the Mediterranean must have been obvious to the progressive Phoenicians, who established stations at Nora and Caralis (Cagliari) about 1000 B.C., though original settlements two centuries before this have been postulated. Subsequently these spheres of influence were much extended, though not all scholars will go so far as ALBRIGHT, who, on the strength of one of the island's many chiselled inscriptions, has been abandoned identification of Tharsish with Andalusia in favour of Sardinia. With the conquest of Tyre and Sidon by Assyria (7th century B.C.) the daughter city of Carthage fell heir to Phoenician colonies on the island by its victory of Alalia in 537 B.C.; the Punic-Elruscan alliance destroyed Hellenic power in Sardinia and Corsica. Eventually the ruthless Carthaginians under Hamilcar and Hasdrubel drove the islanders to the high mountains. The improving economic state is shown by requisitioning of large supplies of wheat for the ill-fated Punic expedition to Sicily in 480 B.C. For long the island was a bone of contention after it came under Roman rule in 238 B.C. Iniquitous exactions in grain and metals led to frequent revolts by the natives. By the Second Punic War it had become a Roman Siberia, mining was extremely active and prosperous, and exile to these workings *damnati ad metallum*, a most dreaded punishment, owing to the prevalence of malaria. One is reminded of Roman or pre-Roman times (Section 7), the remarkable output of Stakhanov miners in Don coal mines, and "Shortest way

Copper and Bronze.—The bronze culture is termed *nuragic*, from the characteristic, *nuraghi*, solid masonry bee-hives, sometimes interconnected to give stout Maginot forts. Statues and weapons have been found in abundance and since no tin occurs on the island it has been suggested that a great store of ingots found near Forraxi is the product of a foundry remelting scrap artefacts (compare Cyprus, Part IV, Section 10, and Fig. 28). "An amazing fluorescence of the metal indus-

tries marks this age. Furnaces and slag have been uncovered and a variety of moulds for casting bronze weapons, also rich repositories of the weapons and implements themselves, including extremely fine sword blades, almost two meters in length, the longest known from the ancient world . . . strange idols with four eyes and four arms, models and shrines and votive boats and animals".

DORO LEVI, 1943.

£1,500,000 Re-Equipment Plan to Develop Exports.

FAR-REACHING plans to develop the export of precision steel tubes, particularly in the European, South American and Eastern markets formerly held by Germany, have been put into operation by the Tube Investments Group of engineering industries.

To ensure equal opportunity in these highly competitive markets, a programme of re-equipment and plant re-assembly, involving an ultimate expenditure of some £1,500,000, has been started at the T.I. Group's steel tube mills in various parts of the country. Many of the modifications are based on the high-speed mass production experience gained during the war.

The programme includes reconstruction of plant for the manufacture of cold drawn steel locomotive tubes at the Sheffield works; additional automatic electric welding mills at the plants in the Oldbury area; and wide reconstruction at the Chesterfield works, which, even before the war, operated one of the biggest heavy steel tube plants in Europe. The scrapping and replacing of machinery, furnaces and tools, etc., and the introduction of new production layouts, are projected for the various works at Birmingham and at Walsall, Wednesbury and Jarrow.

It is estimated that this change-over will take over two years to complete, but the programme has been planned to avoid undue interruption of present high output.

Another step in this British steel tube export drive is now almost completed. The T.I. Group's Trading Missions have already visited and studied most of the potential overseas markets and reported on prospects. Each Mission included engineering technicians and production experts, whose task it has been to examine local engineering needs and prejudices, thus to ensure that these will be precisely met.

Precision steel tubes are an essential part of all power mechanisation, being necessary in the production of all types of land, sea and air transport, and installations of steam, oil and electric power plants. Increasing applications are being developed in the chemical and food industries, building construction, and furniture making.

Nigeria—Its Geology and Mineral Resources.

DURING the war, with Malaya in the hands of the Japanese, Nigeria was the Empire's leading tin producer; thus, if for no other reason, Nigeria made a very valuable contribution to the war effort. As pointed out by Dr. F. Dixey, O.B.E., Director of Geological Survey of Nigeria, in his recent lecture on the above subject at the Imperial Institute, the export of tin ore in 1939 amounted to 14,569 short tons, valued at £2,445,270; great efforts were made to increase the production during the war, with the result that by 1943 the export had risen to about 19,800 tons. Another important war-time

mineral product was columbite, the source of ferro-columbium for the metallurgical industry; over 6,000 tons of the mineral have been produced during the last 10 years, and in 1944, out of a total production of 2,072 tons, 1,000 tons were recovered by re-treating the alluvial tin-mining dumps.

The output of coal from the Enugu Colliery was also greatly expanded from 323,266 tons in 1939 to 668,158 tons in the year ended 31st March, 1945. Considerable quantities were exported to the Gold Coast for the use of the railways. Other mineral products include wolfram and gold and there are also considerable deposits of lead and zinc.

With assistance from the Colonial Development and Welfare Fund, the Geological Survey of Nigeria has been strengthened with a view to completing the geological mapping of the country, so that an intensified search for new mineral deposits can be carried out; in particular the principal tinfields are now being remapped with the object of finding new sources of tin. Part of the new geological mapping will be required in connection with the extensive development of both rural and urban water supplies as an essential basis for the general Colonial Development programme of Nigeria.

Dr. Dixey made special reference to the collection of Nigerian minerals displayed in the Exhibition Galleries at the Imperial Institute, and to the valuable work of the Mineral Resources Department of the Institute in providing information as required on the mineral production of Nigeria and other countries.

Arc Welding Competition.

It is understood that a competition for all those interested in Arc Welding is being organised by the Arcweld Research Construction and Supply Co., 68, Bridle Road, Eastcote, Pinner, Middx. Full particulars of the competition and the awards can be obtained upon application to the Company.

The Light Rolled Steel Products Conference.

THE new Constitution of the British Iron and Steel Federation, which came into operation at the end of May, is based on membership by conferences representing manufacturers of the various products of the industry.

In accordance with the new Federation arrangements, the Light Rolled Steel Products Conference has now adopted a Constitution and appointed as first Chairman (for 1945) Mr. Andrew Jollie, of Steel, Peach and Tozer, the well-known Yorkshire iron and steel firm, and Mr. G. H. Latham, Chairman of the Whitehead Iron and Steel Co. Ltd., is appointed Deputy Chairman of the Conference. Mr. Latham will succeed Mr. Jollie as Chairman of the Conference in 1946, and Mr. John R. Hope, of the Lancashire Steel Corporation Ltd., will be Deputy Chairman.

MICROANALYSIS

CHEMICAL AND PHYSICAL METHODS

APPARATUS METALLURGICAL APPLICATIONS TECHNIQUE

FURTHER, and overwhelming evidence—if such is required—of the importance of the micro-chemist is to be found in the enthralling pages of the recently published U.S. account of the development of atomic energy. When the existence of the newly made element, plutonium (we hold no brief for the somewhat Disneyish names of it and its companion) was first verified, it was essential to work out methods for its separation. This demanded as full an investigation as possible of its chemical properties. We quote from the Report: "Altogether the solving of many of the chemical problems has been one of the most remarkable achievements of the Metallurgical Laboratory. . . . By the end of 1942, something over 500 micrograms had been obtained in the form of pure plutonium salts. Although this amount is less than would be needed to make the head of a pin, for the microchemists it was sufficient to yield considerable information; for one microgram is considered sufficient to carry out weighing experiments, titrations, solubility studies, etc. . . . Successful micro-chemical preparation of some plutonium salts and a study of their properties led to the general conclusion that it was possible to separate plutonium chemically from the other materials in the pile. . . . Thus, by the end of 1942, plutonium, entirely unknown eighteen months earlier, was considered an element whose chemical behaviour was as well understood as that of several of the elements of the old periodic table." It would be impossible to give too high praise to the nuclear physicists, drawn from both sides of the Atlantic, through whose work the dream of many scientists has been attained. But it is well to remember also that other sciences and their practitioners were involved. Without the nuclear physicists, no doubt, no atomic bomb would yet have burst upon the world. Would we be considered insistent if we whispered that perhaps without the microchemists atomic energy might still be a subject for theoretical textbooks.

Forensic Chemistry and Criminal Investigation

By C. G. Daubney, M.Sc., F.R.I.C.

Chief Chemist, Metropolitan Police Laboratory, Hendon.

In the following article an endeavour has been made to deal with some of the applications, in forensic chemistry, of micro-tests for metals; for the sake of completeness certain other topics have been introduced. No mention has been made, however, of the wide field of organic poisons or of subjects which are properly the domain of other branches of forensic science.

IN forensic work it is true to say that as a general principle, every contact leaves its trace. This trace is sometimes readily noticeable, sometimes inconspicuous and frequently minute. It is no exaggeration to say that a criminal can rarely approach the scene, commit a crime and make good his escape without leaving some evidence of his passing, be it in the form of a match or hair, a fragment of paint, grains of poison or scratches on a metal surface.

It is with the application of micro tests to the examination of such traces that this article deals, when the importance of the detection of small amounts of metals and their compounds and the role of micro methods will

become apparent. The interpretation of the results is a very important stage in any analysis and particularly in forensic work when it must stand interrogation in a court of law.

The material submitted for examination covers the widest possible range, including clothing, viscera, food-stuffs, motor vehicles, tools, coins and a multiplicity of other everyday articles which may be connected with a crime, each of which requires its own special treatment.

Poisoning

Metallic poisoning is generally confined to the poisonous compounds of arsenic, antimony, mercury, bismuth, lead and silver, although several other elements have

H. D. Smyth, "Atomic Energy" (H.M.S.O., London, 1946).

been associated with illness and sudden death. In investigating a case of poisoning by such compounds the analyst may hope to be guided by the clinical history and post mortem findings as well as by evidence afforded by dregs in drinking vessels, remnants of food and material found in bottles and packages.

When death has occurred shortly after the onset of symptoms, traces of poison may be found in the stomach contents. A more protracted illness will have led to the more widespread distribution of poison to other parts of the body. In a case of chronic arsenical poisoning the hair and nail clippings will be found to contain arsenic in considerable quantity.

The Reinsch test is of the utmost value here, since it indicates the presence of quite small quantities of the commoner and more lethal metallic poisons such as arsenic, antimony, mercury and silver and can be applied direct to organic matter. The material to be tested is boiled with dilute hydrochloric acid in the presence of copper foil when arsenic and antimony give a dark deposit on the copper whilst mercury and silver leave a silvery or grey deposit. These deposits can be subsequently identified.

For quantitative work a suitable quantity of the organ selected is subjected to wet oxidation and determinations carried out on the resulting solution after suitable purification.

Arsenic.—There are a variety of methods available for the quantitative determination of arsenic in viscera and other material. These include the Gutzeit method,¹ the electrolytic Marsh method² and the method based on the production of molybdenum blue colour.³ The Gutzeit is very suitable for occasional determinations whilst the electrolytic Marsh method has the advantage of providing a permanent record in the form of a deposit sealed in hydrogen. The amount taken for this test should be adjusted to give a deposit representing between 1/1000th and 1/100th milligramme arsenious oxide. The apparatus requires fairly continuous use if reliable results are to be obtained at short notice. The molybdenum blue method has been recently introduced to be used in conjunction with a photoelectric absorptiometer or suitable colorimeter.

Lead. This is a cumulative poison and is most readily found in bone, although the organs of the body as well as the bones normally contain a certain small quantity of this element. The micro determination of lead is effected by a colorimetric comparison of the sulphide against standards after destruction of the organic material by wet oxidation and extraction of the lead by dithizone.⁴

Mercury.—The Reinsch test for mercury produces a silvery deposit on copper foil which, when strongly heated, will volatilise and yield droplets of the metal on a microscope slide. These are characteristic of mercury and form a very sensitive test. In addition to inorganic mercury compounds, mercury is met with in an organically combined form in medicinal preparations and seed dusting powders. The detection of mercury therein necessitates the preliminary destruction of the organic material with acid permanganate.⁵ Dusting powders are sometimes mixed with cereal seeds to reduce the depredations of birds and rodents during the early

stages of growth in the field and thus provide a means of differentiating such seed from untreated seed. This has proved of great value in cases of larceny. The proportion of powder to seed is low and the quantity of mercury present is such that only a micro test serves to detect this element.

Alkali cyanide. In a case of cyanide poisoning it was necessary to establish whether potassium cyanide or sodium cyanide was the cause of death. A man was found dead in his bed upstairs although attendant circumstances pointed to his having taken poison whilst downstairs. The stomach contents were analysed for sodium, potassium and cyanide and the results examined in conjunction with the knowledge of the last meal taken. These indicated that sodium cyanide was the cause of death, a conclusion in keeping with the subsequent discovery of a few particles of fused sodium cyanide adhering to the man's handkerchief. This form of cyanide had been readily accessible to him at his place of work. Experiments also showed that fused sodium cyanide is not rapidly attacked by dilute hydrochloric acid under the conditions obtaining in the stomach. This may well have accounted for the apparent time lag which allowed the deceased to get upstairs to his bed before death ensued. In another instance a positive reaction by the pyridine-benzidine hydrochloride test⁶ for cyanide in one of four washed out teacups confirmed an attempted murder of an old man by a gardener who placed half a gramme of potassium cyanide in a cup of tea.

Cobalt.—A workman engaged in a factory producing high speed tools was taken ill and subsequently died. The question of industrial poisoning arose and examination of the deceased's lung revealed the presence of cobalt. This was determined colorimetrically by means of the Nitroso-R-salt reagent⁷ against standards. The toxicity or otherwise of cobalt dust proved to be a question of considerable complexity since little data is available on this subject.

Phosphorus.—Rat poisons containing yellow phosphorus have been taken with fatal results. Elementary phosphorus can be detected in organs by steam distillation⁸ when a phosphorescent glow can be seen in a darkened room. If this test fails to give a decisive result the minced tissue is treated with nascent hydrogen generated from zinc and sulphuric acid^{9, 10} when phosphine is produced. This is absorbed in silver nitrate to give silver phosphide from which phosphine can be regenerated by nascent hydrogen or converted to phosphate.

Breaking Offences

Under this heading can be included a wide range of crimes such as housebreaking, safebreaking and larceny and in considering them it will be necessary, for completeness, to deal with some non-metallic bodies.

When an unlawful entry is made into a dwelling-house or other premises it is often necessary to force a door or window. In so doing several clues as to the intruder's movements may result. Fibres of clothing may be left adhering to a jagged piece of wood, an impression of the tool used left on the woodwork, paint transferred from a window to a jemmy, particles of

1 British Pharmacopoeia, 1932.

2 Aumonier, F. S., *J. Soc. Chem. Ind.*, 1927, **46**, 341T.

3 Milton, R. F. and Duffield, W. D., *Analyst*, 1942, **67**, 279.

4 Roche Lynch, G., Salter, R. H., and Osler, T. G., *Analyst*, 1934, **59**, 787.

5 Jacobs, M. B., "Analytical Chemistry of Industrial Poisons" New York, 1941, p. 188.

6 Aldridge, W. N., *Analyst* 1944, **69**, 262.

7 McNaught, K. J., *Analyst*, 1939, **68**, 23; 1942, **67**, 97.

8 Mitscherlich, J., *J. Prakt. Chem.*, 1855, **68**, 238.

9 Dumas, C. B., 1856, **43**, 1126.

10 Landonot, C. R., 1861, **52**, 1197.

glass caught up in the visitor's clothing who may also pick up carpet fibres on his footwear. If now the object of the breaking is to rifle, for example, a safe or electric light slot meter, further evidence may well be forthcoming. A safe is usually surrounded with a fireproof packing of typical composition which, once spilled, has a habit of finding its way on to the clothing of the safe-breaker, albeit in minute quantity, due to its fine state of subdivision. Any tool used to force the safe will generally leave typical scratch marks on the metal and collect paint in the process. If, on the other hand, an explosive is used then the products of combustion afford a clue as to their nature and search can be made for evidence of such explosive in the clothing or other possessions of the suspect.

From this brief outline it will be apparent that there is much scope for tests on a micro scale. These will include the examination of traces of paint by spectrographic means, of dusts from the safe packing and elsewhere, of any burnt and unburnt explosives, of material fibres, of glass fragments and scratch marks: all inconclusive perhaps if taken singly, but collectively forming a strong link in the chain of evidence.

Pocket knives often repay examination for traces of foreign metals and other bodies. A strong blade can be used to cut the zinc gauze frequently found over larder windows, the heavy tarred felt all too common on property damaged by enemy action, copper wire used for a variety of purposes or to prise open small cash boxes. In all such cases the spectrograph is an invaluable instrument.

Road Accidents

The violence of a road accident inevitably causes the colliding bodies to bear marks of the impact to a greater or lesser degree and involves the transfer of matter from one to the other. When, for example, a car and cycle come into collision some paint will be exchanged. A comparison by spectrographic means of any such paint found in the areas of impact will afford evidence of great value in confirming the facts of the case. When dealing with the cellulose paints so commonly used to-day the microspectroscope affords a means of examining any dyestuff present. In other accidents a pedestrian may be knocked down. Here there may be a transfer of grease from some part of a car to his clothing whilst the car itself may receive blood, hair, skin and even the imprint of the clothing. It is a matter of common observation and often of regret that a car exudes grease from hubs, sump, gearbox and back axle. These differ in quality. For this reason the nature of grease on the clothing may be of great importance.

On an occasion when a car with highly polished wings struck a woman wearing a tweed coat, imprints of the fabric were found on the wing. By photographic means it was shown that the impression on the wing agreed with the pattern of the coat fabric.

If hairs are found on a vehicle involved in an accident, their human origin must be confirmed and a comparison made with samples taken from the injured person. Many vehicles, especially public conveyances, are fitted with wooden safety guards. After an accident splinters of wood may be found embedded in the victim's clothing. The nature of the wood forming these splinters must be ascertained and compared with wood taken from the safety guard or other damaged parts of the vehicle.

11 Evans, J. and Jones, A. O., *Analyst* 1929, 54, 134.

It is often necessary to confirm whether a driver of a motor vehicle was under the influence of drink at a given time and chemical tests can help to substantiate the clinical findings. When alcohol is consumed a proportion finds its way into the blood stream and thence to the urine and the quantity present therein bears a definite relation to the amount consumed. The concentration of alcohol in blood and urine, after reaching a maximum, decreases at a steady rate, so that it is possible to calculate the amount present at a stated time prior to the taking of the samples. A micro method has been devised by Evans and Jones¹¹ for the estimation of alcohol in body fluids. A current of air is passed over a known small volume of blood or urine contained in a tube heated to 85° C. in a water bath and the volatile alcohol absorbed in a known volume of acid dichromate. The reduction of the dichromate is a measure of the alcohol present in the sample.

Abortion

In investigating cases of criminal abortion a variety of pills, liquid preparations and syringes as well as clothing and bedding require examination. Any syringe found in this connection may have been used for the injection of soapy water and confirmation of this calls for the detection of any trace of soap therein. The residue in the tube or bulb of a syringe is frequently in the form of a dried calcium soap produced by the action of hard water although other syringes are found still wet with soapy fluids. Carbolic soap residues can be confirmed by the sensitive reaction of phenols.

Coining

Counterfeit coins are usually cast in plaster moulds from base metal, solder and such like material and the edges of the coins subsequently milled with a suitable wheel. The finished articles are sometimes of a bad colour, underweight, without the ring of a genuine coin and possessing imperfections to a greater or lesser degree. Such counterfeits often pass muster for a sufficient time, for it to be very difficult to trace them back to their maker. Once a suspect is located, various pieces of apparatus and plant come to light. In addition to the examination of the moulds, traces of metal in pans and ladles must be analysed both qualitatively and quantitatively for comparison with the metal of the counterfeits as must any particles of metal adhering to the suspect's clothing and on the milling tools. Preparations for producing the proper lustre on the counterfeits have been encountered and the examination of the collected articles seldom fails to establish the purpose for which they were used.

Arson

This is regarded as one of the more serious of crimes and expert searching of the scene of a fire for evidence of deliberate fire raising is a matter of great importance. Much material can often be collected.

Considerable research has established that even a burnt match head can afford some indication of the brand and this may enable it to be linked with the brand found in the suspect's possession. Again, a volatile inflammable solvent is not of necessity completely consumed in a fire and its recovery by steam distillation from a mass of sodden debris, and subsequent identification, may link it with a certain source of supply. This is especially true of hydrocarbon oils of which many grades are available with characteristic boiling ranges and other physical properties.

Incendiary devices or infernal machines have been recovered from fires and their somewhat elaborate manufacture from candles, rope, sacking, wood, wire and nails has provided sufficient evidence to secure convictions. Items such as candle grease, candle wick, and rope all possess important features of composition and construction whilst saw marks on wood and the distinctive markings on nails can afford useful data.

Miscellaneous

A large variety of problems outside the general topics already discussed are also encountered. Thus it may be of importance to obtain a clue as to the occupation of the owner of some clothing. Certain oil stains have indicated a worker with cold bitumen road dressing; metallic particles of a particular composition embedded in the sole of a shoe pointed to an aircraft worker; precious metal dust, a jeweller; and putty, a glazier.

A Micro-Separatory Device

By J. T. Stock and M. A. Fill.

THE device shown in Fig. 1 is useful in semi-micro organic preparations, etc., for extraction from aqueous medium by repeated treatment with ether or similar solvents. It is designed to permit efficient separation of the immiscible layers, allowing small portions of solvent to be used, even when the volume of solution to be extracted is considerable.

The upper portion of the syphon tube A slides easily in cork sleeve B which is held in a clamp attached to a retort stand. The lower end of A is funnel-shaped, and of an external diameter 2 mm. less than

the bore of the tube in which the extractions are performed.

Suction device C consists merely of a 50 ml. measuring cylinder partially filled with mercury and closed with a cork, in which slides T-tube D. When the tap is closed, readily-controllable suction may be

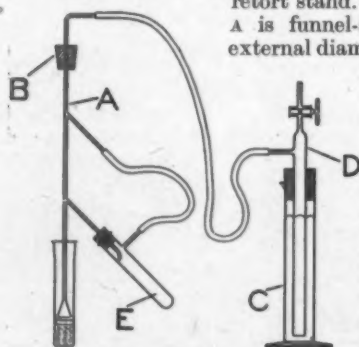


Fig. 1.—A micro-separatory device.

applied to the syphon tube by raising the T-tube.

A stoppered boiling tube is used for the extraction (a Stoke's tube, as used in milk analysis, is particularly useful). The medium is introduced and shaken with a ml. or so of solvent, after which the mixture is lightly centrifuged to separate the two layers. The syphon tube is then carefully lowered into the liquid until the funnel end is about 2 mm. below the interface of the two layers. Gentle suction is then applied until the solvent layer is drawn as completely as possible into the funnel. On increasing the suction slightly, a few air bubbles are drawn into the funnel, thus sweeping with them practically the whole of the residual solvent layer. The syphon tube is then pushed down until the interior and exterior levels of liquid are identical, when the tap is opened and the T-tube D is depressed to its original position. After pushing the funnel end well down into

Cases of fraud have involved from amongst a miscellaneous collection of articles—the analysis of "gold dust," rings and blocks of metal for gold and silver metals usually conspicuous by their absence.

Suspected sabotage has required the study of abrasives when the physical state as well as the chemical composition of foreign matter in engine sumps and machinery has been of significance.

Conclusion

It is hoped that this article has given some insight into the wide variety of chemical analyses and examinations required in connection with criminal investigations and other forensic work and of the types of problems to which existing methods have been adapted. Many topics have perforce been omitted. Enough will have been written to show that many methods must be employed, on the results of which may depend a successful prosecution or proper acquittal in a court of law.

the liquid, the tap is again closed. Suction is then applied so that the liquid rises in the syphon tube and the solvent layer runs over into receiver E. The liquid junction is easily visible, and, since the bore of the syphon tube is only 2.5 mm., almost complete separation of the layers is possible. On opening the tap and raising the syphon tube the aqueous medium returns to the boiling tube for subsequent extractions, which are carried out in the same way.

When the laboratory is warm, the entry of the first drop of extract into the receiver may cause the column of liquid in the syphon tube to fall sharply. A drop of solvent placed in the receiver before commencing operations overcomes this.

A Modified Conway Microburette

IT is well known that for many purposes a horizontal microburette is more convenient than a vertical one, and probably the best known of the many horizontal burettes proposed from time to time is that of Conway. The Conway burette is designed to deliver 0.25 ml. however, and many occasions arise when a burette with a larger capacity would be useful. Particularly would this be so if the burette still retained the many advantages of the Conway type, such as the ease of control of flow because of constant head, the reservoir, the simplicity of reading any portion of the graduations while seated.

Such a burette has been described by Levvy.² If the graduated portion of the burette has not a greater internal diameter than 3 mm., it will be found that the meniscus remains vertical when the tube is turned into the horizontal position. Such a tube was found, over a large number of deliveries of 1 ml. of water, to vary only by just over 0.1 per cent. Reference to the comparative figures given by Conway for a vertical burette of 2-ml. capacity suggest that the accuracy obtained with the horizontal type is as great as that to be expected from a vertical microburette of normal pattern.

Several tubes with 3 mm. and smaller bores may be prepared and used interchangeably in the Conway apparatus. Thus the one instrument is capable of delivering a considerable range of volumes. With the widest bore it is possible, without making the tube too long, to obtain a delivery of up to 4 mls. A rate of movement of the meniscus of 1 cm. per second is maintained.

¹ E. J. Conway, *Micro-Diffusion Analysis and Volumetric Error*, London, 1959.
² G. A. Levvy, *Chem. and Ind.*, 1945, 4.

METALLURGICAL DIGEST

Blackened Stainless Steels

By P. B. Strassburger.

THE most conspicuous feature about stainless steels, and one which usually appeals first to both designers and users, is their permanent lustre. In certain wartime parts, such as for rifles in the army, depth sounders in the navy and for gyroscopes in the air, to mention only a few such parts, this quality is not permissible. To meet needs of this type a new method has been developed which not only blackens the metal with a durable finish, but at the same time slightly improves the well-known corrosion resistance of the surface of the steels.

and adding machine parts, springs, windshield wipers, valves, camera parts and other items requiring all black or partially blackened surfaces. Other potential applications are for wrist watch cases, jewellery parts, nails and and screws in cinema projectors and sound equipment and for dark-room photographic equipment.

In stainless steels, a thin invisible film of oxides, chromium, iron and nickel, gathers on the surfaces of the steels, and it is the stability of this film which gives the measure of the corrosion resistance. There is marked enrichment of chromium in the film as compared with the underlying steel and this enrichment increases in relation to the percentage of chromium in the alloy and with the degree of polish. To remove the oxides of this surface film so as to change colour and brightness to another colour with reduced reflectivity, presents a difficult problem due to the very complexity of the oxide components. Colour may be changed by burning on an oxide film in a high temperature controlled atmosphere but such a method is not satisfactory. The best method is limited to chemical or electrochemical means.

In a new blackening process as finally developed, a coating is formed in a non-aqueous bath at moderately high temperature. This coating is an oxide of the metal and not a hydroxide, hence the reason for its endurance when exposed to heat and atmospheric changes. Very little equipment is

TABLE I.—COMPARISON OF CORROSION RATES OF BLACKENED AND UNTREATED STAINLESS STEELS (RATES EXPRESSED IN GRAMS/CM²/50 HOURS).

Steel	0.5% HNO ₃ Boiling	2.5% HNO ₃ Boiling	0.5% HCl 50° C.	1.0% HCl 50° C.
12% Cr.	0.0023	0.1040	0.9930	1.4800
12% Cr.-Blackened	0.0000	0.0080	0.1080	0.4730
17% Cr.	0.0008	0.0004	2.7200	2.9400
17% Cr.-Blackened	0.0000	0.0000	0.0505	0.8820
18-8.	0.0012	0.0000	0.6193	0.0190
18-8-Blackened...	0.0000	0.0000	0.0007	0.0012

required for the process. All the fabricator requires is a steel tank of suitable size, an adequate method of heating, and some holders or baskets in which the parts are placed during immersion. Good practice calls for a cover and a stirrer to assist in keeping the coating uniform.

In treatments, parts to be blackened are first cleaned to remove all scale, grease, oil or other foreign substances, then they are immersed in a molten solution of dichromates, preferably sodium dichromate raised to a temperature of 390° to 400° C. The time of immersion varies and depends on the number and size of the parts and the grade of stainless steel from which they are made. In Fig. 1 are given the rates of coating formation in the molten dichromate bath for three types of stainless steel. When sufficiently coated, parts are removed from the hot bath, allowed to cool to room temperature, rinsed in hot water to remove salts and then dried with an air-hose. The use of oils and waxes to improve the lustre of the black finish has been found successful.

In Table I is given a comparison of the corrosion rates of blackened and untreated stainless steels in weak nitric and hydrochloric acid.

Recrystallisation of Aluminium

By W. A. Anderson and R. F. Mehl

WHEN a cold-worked metal is heated to a temperature at which recrystallisation will ensue, nuclei of new grains, essentially strain free, appear and grow. As the process proceeds, nuclei continue to appear and to grow, until the cold-worked matrix has been entirely consumed

and recrystallisation has been completed. The rate of recrystallisation is determined by the rate at which nuclei form and the rate at which they grow. The rate of nucleation N is the number of nuclei that form in unit time in unit volume of the unrecrystallised matrix and the rate of growth G is the increase in radius of the recrystallised grain per

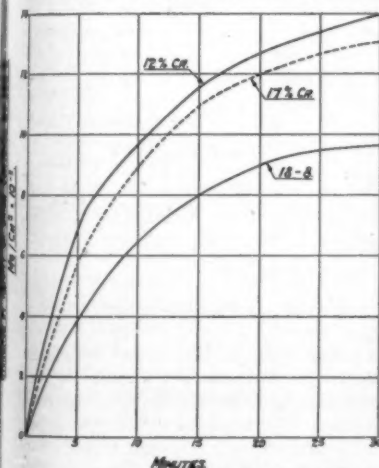


Fig. 1.—Rate of coating formation in the molten dichromate bath for blackening stainless steel.

The need for blackening stainless steels is not merely a wartime necessity, as there is rather a large group of peacetime applications which have shown the need for dulling the finish of these steels. In many products, especially those made from wire, bars, and forgings, the principal reason for using stainless steels is not their lustre, but their high strength properties and special magnetic or electrical characteristics, coupled with corrosion and heat resistance. Some potential applications of blackened steels might therefore be for oven tops, typewriter

From *Metals and Alloys*, 1945, vol. 21, No. 5, pp. 1309-1312.

From *Metals Technology*, 1945, Vol 12, No. 2 and A.I.M.E. Technical Publication, No. 1805, pp. 1-28.

TABLE I
COMPOSITION AND INITIAL GRAIN SIZES OF ANNEALED ALUMINIUM SHEETS

Mark	Nominal Thickness	Composition				Grain Size Grains per sq. mm
		Si	Fe	Cu	Ti	
A.	0.015	0.008	0.0008	0.022	0.002	530
B.	0.125	0.01	0.03	0.01	—	598
C.	0.015	0.004	0.004	0.006	0.001	484
D.	0.015	0.004	0.004	0.006	0.001	345
E.	0.015	0.004	0.004	0.006	0.001	60

unit time. A study of the recrystallisation of aluminium in terms of N and G has been made using aluminium over appreciable ranges of the variable time, temperature, degree of deformation and original grain size.

Five grades of high-purity aluminium were used for the tests and their compositions are given in Table I. These materials were received in their cold-rolled condition and strips were cut from them, with their long dimension perpendicular to the direction of rolling. These cold-worked strips were recrystallised in order to provide a uniformly small and equiaxed grain size, and for this purpose, lots A, B and C were annealed at 300° C. and lots D and E at 350° C. The grain size of the recrystallised materials are also given in Table I. Cold deformation was supplied by simple elongation in a testing machine. Parallel gauge lengths 2 cm. apart, were marked along the length of the strips, and the distribution of elongation over the whole length of the strips was measured between these gauge marks. The elongated samples were heated for recrystallisation in a fused salt bath, mechanically stirred. The course of recrystallisation was observed by the method of statistical analysis of a series of samples, removed from the bath in groups of four to six samples at a succession of time intervals and studied separately. From the data accumulated in this manner, it was possible to determine: (1) the fraction recrystallised as a function of time, yielding isothermal recrystallisation curves; (2) the rate of nucleation N , and (3) the rate of growth G .

Measurements made of cold-worked high-purity aluminium in sheet 0.015 in. thick show that in these thin sheets the recrystallised grain size is greater than the sheet thickness, introducing special features into the recrystallisation process, and such recrystallisation is termed "two dimensional" recrystallisation. In such sheets it was found that N increases with time up to 30 to 40% recrystallisation and that G is variant with time. Both N and G were found to increase exponentially with temperature, and both increase with increasing deformation,

but N increases more rapidly than G , accounting for the smaller final recrystallised grain size after high degree of deformation. Activation energies calculated from the temperature coefficient of N and G ; both Q_N (nucleation) and Q_G (growth) decrease with increasing deformation, but Q_N decreases more rapidly than Q_G . Measurements were also given on the "induction period" as a function of temperature and percentage deformation.

Similar investigations were made, with similar results, for the recrystallisation of thick sheets, 0.125 in. in thickness. In these, the recrystallised grain size is much smaller than the sheet thickness, and such recrystallisation is termed "three-dimensional" recrystallisation. The thick sheet recrystallised less rapidly than the thin sheet, owing apparently to an originally higher degree of preferred orientation in the thin sheet and shows that the degree of preferred orientation

is a variable affecting recrystallisation. The problem of the quantitative relationship between "two dimensional," and "three dimensional" recrystallisation was also investigated and methods of interconversion are proposed. It was also found that the thickness of the sheet is a variable affecting recrystallisation owing to the restrictive effect of sheet thickness on nucleation.

The rate of recrystallisation increases markedly with decrease in initial grain size, and, in coarse-grained material, N was observed to decrease with time. Experiments were made at high degree of deformation, 90% by cold-rolling, which suggest that N initially increases with time, passes through a maximum and then decreases. These investigations show that N steadily increases with deformation, but that G reaches a limiting value at about 15% deformation and after that changes little.

In general, the observed behaviour of N and G has been used to provide a basis for recrystallisation behaviour as represented on conventional recrystallisation diagrams, and has been used also in discussing the theory of recrystallisation. The evidence obtained indicates that recrystallisation nuclei form at points of high stress.

Grain Size and Properties of Sand-Cast Magnesium Alloys

By R. S. Busk and C. W. Phillips

WITH most cast metals the grain size may vary within wide limits, depending upon the conditions at the moment of freezing, and these conditions are subject to control in magnesium-base alloys, by proper melting and superheating techniques, enabling the production of quite uniform and fine-grained castings, almost independent of section thickness. Data are presented giving the relationship between grain size and mechanical properties, the combined effects of grain size and microporosity, and the factors influencing the grain size of sand castings.

Tests were limited to the common sand-casting alloys containing aluminium, zinc and manganese. Variations of grain were produced by varying the thermal treatment of the molten metal and by heat-treatment

of the casting. The effect of superheating 260° to 370° C. above the liquidus is to produce a finer grained casting than would have been produced by omitting such a superheating treatment, and heat-treating the solidified alloy at approximately 410° C. causes grain growth with increasing time of heating. Tensile, impact and fatigue values were obtained for different grain sizes and the results obtained in summarized form are given in Table I.

All data in Table I, except for one alloy, are graphical averages obtained by plotting original data for tensile strength, tensile impact resistance and endurance limit against average grain diameter. The exception is the data for the fatigue strength of H-HT where experimental values are given because of their excessive scattering. A linear relation is found between the mechanical properties for each of the three

From *Metals Technology*, 1945, Vol. 12, No. 2, and A.I.M.M.E. Technical Publication No. 1771, pp. 1-11

TABLE I.—EFFECT OF GRAIN SIZE ON PROPERTIES OF MAGNESIUM ALLOYS.

Alloy.	H-HT 9% Al, 3% Zn, 0.3% Mn			H-HTA 6% Al, 3% Zn, 0.3% Mn			C-HTA 9% Al, 2% Zn, 0.2% Mn		
	4	10	20	4	10	20	4	10	20
TENSILE PROPERTIES.									
Yield Strength, tons per sq. in.	13.8	12.6	11.4	21.2	18.6	16.6	25.0	23.5	22.5
Ultimate Strength, tons per sq. in.	40.8	37.2	33.8	39.8	37.0	34.0	39.4	35.6	32.8
Elongation, %	14.4	12.2	9.4	4.4	4.4	4.4	1.4	1.4	1.4
Impact, ft.-lb. . . .	105	83	66	43	33	27	26	16	8
FATIGUE PROPERTIES.									
10 ⁵ Cycles	20.5	17.9	—	21.2	19.1	17.5	21.2	19.1	17.5
10 ⁷ Cycles	15.0	13.5	—	15.8	13.7	12.2	15.8	13.7	12.2
10 ⁸ Cycles	13.0	11.8	—	14.2	12.0	10.3	14.2	12.0	10.3
Notch Efficiency = Notched Value Unnotched Value	—	—	—	0.70	0.63	0.52	0.50	0.59	0.63

TABLE II.—TENSILE AND METALLOGRAPHIC DATA ON C-HTA MACHINED FROM A SERIES OF PRODUCTION CASTINGS.

No.	Tensile Strength Tons per sq. in.	Compound Rating	Average Grain Size	Size Large Grain	Porosity.		
					Micro	X-Ray	Fracture
1	13.4	4-5	15	30	0	—	—
2	14.0	4	9	15	0	—	—
3	13.3	3-4	10	20	0	—	—
4	11.0	4-5	9	15	0	—	Yes.
5	9.5	4	15	30	0	—	Yes.
6	13.2	3-4	9	50	0	—	Yes.
7	11.2	3-4	15	—	0	No.	Yes.
8	15.1	2-3	15	—	0	No.	No.
9	9.3	2-3	15	—	0	No.	Yes.
10	8.8	4-5	5	15	0	Yes.	Yes.
11	16.5	2	15	—	0	No.	No.

alloys and $\log\left(\frac{1}{D_s}\right)$ is obtained where D = the diameter of the grain in inches. The results obtained are on separately cast test bars in which all variables except grain size were held constant.

Since the ultimate value of data, such as is given in Table I, is an understanding of the effect of grain size on the serviceability of castings, it is important to judge the relative importance of grain size compared with other possible defects. One such comparison was made with data showing the effect of porosity on the mechanical properties of a magnesium alloy having a grain size of 12, where the tests showed the porosity to completely overshadow the grain size. In bars cut from two production castings, the grain size, compound rating, microscopic porosity, radiographic porosity and

porosity visible at the fracture were determined and are given in Table II. The results obtained show that, although grain size has a deleterious effect on mechanical properties, the effect is small compared with that of other variables.

Since it is possible to superheat magnesium-base alloys, the grain size of commercial castings can be kept well under control. The average size is well under 0.006 in. and it is rare to find any larger than 0.030 in. Comparing this range with the data on properties, it is seen that the magnitude of the property effect is small. Thus, while grain size does have a positive effect on mechanical properties and should, therefore, be carefully controlled, such control is available, and emphasis should be placed on other variables that adversely affect mechanical properties.

Heat Treatment of Magnesium Alloys

By D. Burke, R. F. Thomson and W. E. Jominy

DATA is given on the effects of pouring temperature, initial structure, heating rate prior to solution treating, solution temperature, solution time, cooling rate from the solution temperature, ageing temperature and ageing time on the resultant static physical properties and microstructure of a fine grained magnesium alloy. A brief study of dimensional changes during heat treatment is also included.

From *The Foundry*, 1945, vol. 73, No. 4, pp. 100-103, 236 and 238.

The data reported were obtained on an alloy containing approximately 6.0% aluminium, 3.0% zinc, 0.15% manganese, 0.30% silicon, 0.05% copper, 0.01% nickel, 0.30% other impurities and the remainder magnesium. The results were obtained on standard 0.5 in. test bars cast at 700° to 800° C., after superheating for 15 minutes above 870° C. with a maximum temperature attained during

superheating of 912.5° C. The resulting grain size on all test bars was between 0.003-0.005 in. average grain diameter. In heat-treating the test bars were placed in a furnace below 260° C., heated to 345° C. and held for 15 minutes, heated from 345° to 385° C. in 2 hours, held at 385° C. for 12 hours, air cooled, aged at 175° C. for 16 hours and air cooled. Tests made on the as-cast material, on the solution treated material and on the solution treated and aged material, are given in Table I.

TABLE I.—EFFECT OF HEAT TREATMENT ON PHYSICAL PROPERTIES.

Condition	Yield Strength Tons per sq. in.	Ultimate Strength Tons per sq. in.	Elongation % on 2 in.	Brinell Hardness
As-Cast	6.5	13.4	7	62
Solution Treated	6.6	18.3	15	60
Solution Treated and Aged	8.2	17.4	6	72

The results obtained from the various tests show that there is no significant effect of variable pouring temperature on the heat-treated and aged physical properties in the range 1268° to 1428° C., and also that the initial structure has little effect on the same properties. The heating rate prior to solution treatment has a slight effect on physical properties in that slowly preheated material has slightly superior properties. Data on solution temperature indicate that temperatures as high as 400° C. produce satisfactory properties if no burning occurs during heat-treatment, and that temperatures as low as 370° C. also produce good properties. To prevent burning and to ensure complete solution of the beta constituent a temperature of 385° C. is selected in treatment. The tests also show that satisfactory physical properties in sand cast test bars are produced by solution times as short as 6 hours, and that ultimate tensile strength decreases appreciably with cooling rates slower than 66 seconds.

As regards the effect of ageing temperature and ageing time on the physical properties, the data obtained show that no appreciable ageing takes place at 120° C. and this was borne out by metallographic examination which showed a solution treated structure after 16 hours ageing at 120° C. Ageing at 230° C. effects a decrease in the values obtained for ultimate strength and yield strength by ageing at 175° C. Ageing at 175° and 230° C. shows that the more rapid

ageing produced by the latter temperature promotes a rapid decrease in the ultimate tensile strength and an early increase in the yield strength. No significant changes in properties were obtained by ageing for 16 or 160 hours at 175° C. Ultimate tensile strength is not seriously affected by the amount of lamellar precipitate formed during ageing but yield strength appears to be directly affected.

A brief study of the dimensional changes occurring during heat-treatment was made by machining test specimens, $\frac{3}{8}$ in. diameter, 3 in. long, from 1, 2, and 3 in. cast test bars, and measuring them in the as-cast, after solution treatment, and after solution treating and ageing conditions. Dimensional changes during treatment were found to be of the order of 0.01 in. per foot.

with a Profilometer and were expressed as root mean square in microinches of the departure of the contours from a plane surface. A summary of the results obtained from the polished steel specimens are given in Table 1, and show the finishes to vary from 9 to 65 microinches. The weight of steel removed by polishing was also measured. The application of oil or grease to polishing wheel heads of a given grain size materially reduced both the amount of metal removed and the Profilometer readings, while the finish produced with the greaseless compound was intermediate between that made by dry, fine-grain polishing and grease polishing.

Methods of Polishing Steel and Their Effects Upon the Protective Value of Electroplated Coatings

By G. A. Lux and W. Blum

THE results are dealt with of an investigation upon the protective value of plated coatings that result from differences in the method and degree of polishing of the metal prior to plating. The complete investigation was planned to include steel, brass and zinc-base die castings, and so far the work has been confined principally to the polishing and plating of cold-rolled steel and exposure of specimens to the atmosphere in three locations. The exposure tests of the steel have been completed.

From *Journal of Research, National Bureau of Standards*, 1945, 50, No. 4, pp. 295-324.

The steel used for the tests was a special cold-rolled S.A.E. 1010 steel (0.08 to 0.13% carbon) supplied in flat strips, 6 ft. long, 4 in. wide and 0.031 in. thick, having a smooth bright finish and giving Profilometer readings of 2 to 4 microinches. Strips of this steel were polished with wheels to which abrasives of specified grain sizes from 90 to 320 were glued. Results were obtained of polished-steel specimens, grease-polished specimens and on specimens finished with a "greaseless" aluminium oxide compound. The resultant finishes were measured

The polished specimens were subjected, prior to plating, to degreasing with trichlorethylene in a vapour degreaser, electrolytic alkaline cleaning, rinsing in water, dipping in acid and a final rinsing in water. Specimens were then plated with copper, nickel and chromium of controlled thicknesses, buffed in the case of dull nickel and copper plated specimens, and exposed to the atmosphere at New York, N.Y.; Sandy Hook, N.J.; and Washington, D.C. The extent of rusting observed at periodic inspections was expressed on a numerical scale, and the average results over a period

TABLE 1. SUMMARY OF SURFACE FINISH AND METAL REMOVED OF POLISHED STEEL SPECIMENS.

Grain Size In Final Polish	Surface Finish Before Final Polish	Polishing Pressure lb.	Number of Passes per Strip	Average Number of 6-ft. Strips per Wheel Head	Total Metal Removed ($\times 0.00001$ in.)			Profilometer Value (Microinches)		
					Max.	Min.	Average per Pass	Max.	Min.	Mean
90	Cold-rolled	35	2	18	110	75	46	85	44	65
120	90-grain	30	2	11	78	69	37	42	39	41
150	Cold-rolled	25	3	7	108	83	32	37	26	32
150	90-grain	25	3	5	108	78	31	28	21	25
150	120-grain	25	3	5	94	86	30	29	23	26
180	150-grain	25	3	8	102	75	30	36	24	30
220	Cold-rolled	25	3	4	91	64	26	28	19	24
220	90-grain	25	3	4	89	61	25	28	19	24
220	150-grain	25	3	4	89	72	27	28	17	23
220	180-grain	25	3	4	86	55	24	24	21	23
320	Cold-rolled	25	3	2	72	39	19	19	12	16
320	220-grain	25	3	2	61	30	15	17	10	14
Oiled 220	Dry 220-grain	45	3	6	22	11	6	16	12	14
Oiled 320	Dry 320-grain	40	3	3	19	11	5	11	6	9

TABLE 2. EFFECT OF SURFACE FINISH ON PROTECTIVE VALUE OF BUFFED DULL-NICKEL PLATING ON STEEL.
(0.00075 IN. FINAL THICKNESS OF BUFFED DULL NICKEL. 0.00001 IN. OF CHROMIUM)

Surface Finish	Outdoor Exposure (T = Total Percentage Score).								Accelerated Test (Spots per Specimen)			
	New York (57 weeks)		Sandy Hook (57 weeks)		Washington (61 weeks)		Average 3 Locations		Salt Spray 100 Hr.	Conden- sation 240 Hr.	Ferroxyl 10 Min.	Hot Water 6 Hr.
	T.	Deviation from Average	T.	Deviation from Average	T.	Deviation from Average	T.	Deviation from Average				
Cold-rolled	18	0	29	+ 2	85	- 5	43	- 2	1	0	1	1
90-grain	20	+ 2	30	+ 3	93	+ 3	48	+ 3	40	0	4	1
150-grain	18	0	25	- 2	89	- 1	44	- 1	6	0	4	0
220-grain	17	- 1	23	- 4	88	- 2	43	- 2	0	0	3	0
220 Oiled	19	+ 1	29	+ 2	93	+ 3	47	+ 2	0	0	2	0
320 Oiled	21	+ 3	29	- 7	87	- 3	43	- 3	20	0	0	—
320 Oiled	19	+ 1	27	0	92	+ 2	46	+ 1	4	0	0	—
Superfinished	18	0	32	+ 5	89	- 1	46	+ 1	0	0	0	—
Average	18	± 1	27	± 3	90	± 3	45	± 2	—	—	—	—

such as one year, were expressed as "percentage scores." The effect of surface finish on the protective value of buffed dull-nickel plating on steel is given in Table 2. Comparison of the various scores shows that wide differences in the surface finish of the

steel had no significant effects on the protective value of the plated coatings. Results with accelerated tests, such as the salt spray moisture-condensation, ferroxy and hot water tests, were not as reproducible and consistent as the atmospheric tests.

Sand Problems in Steel Castings

By S. H. Ljunggren

THE problems associated with the production of sound steel castings are considerable. Many are concerned with the sands used for the preparation of the moulds, and the paper by the author under the above title is the first official report presented by the Jernkontoret's Steel Sand Research Committee. It begins with a description of the fundamental requirements of the sand mould in general and cites the most common defects on steel castings caused by faulty moulds. The organisation and status of sand research in different countries, including Sweden, is briefly reviewed.

The production of unfinished steel castings in Sweden is at the moment estimated to 23,000 metric tons a year. The sales value of these castings is about 30 million Swedish crowns. The author discusses the different variable costs involved in the production of steel castings as related to the purchase of the sand, mould drying, cleaning and chipping (including welding) as well as the cost of castings scrapped because of sand defects. It was found that these costs averaged about 21% of the total manufacturing cost of carbon steel castings.

In one section the raw materials, sand and clay, especially the types used in Sweden, are described. The molecular structure and the most important characteristics of the sand and clay minerals are discussed in detail. The consumption of new sand in Swedish steel foundries amounts to 18,000 tons a year, valued at about 700,000 Swedish crowns. Only domestic sand is used at present. The new sand used is either washed clay-free sand or sand obtained through crushing sand stone or silica rock. The SiO_2 -content generally exceeds 97%. Both domestic and foreign clay is used. The clays may be classified as non-plastic kaolin, plastic kaolinitic clays and highly plastic bentonites. The last group shows the best bonding properties.

The main part of the paper is devoted to sands for dry sand moulding used in Swedish steel foundries

and to the results of detailed investigations in the laboratory, and also in the steel foundry, on some of these sands.

The sands investigated, all of them synthetic, showed very diverse characteristics, especially with respect to grain size, grain distribution, permeability and strength. The permeability, however, very distinctively increased with increasing grain size and more uniform grain distribution.

The tendency for sand to adhere (burn on) to the castings, and the formation of scabs and buckles was studied on specially designed test castings. The temperatures at the surface of a test mould wall were measured. The contact zone between steel and sand has been subjected to study under the microscope.

The investigations suggest that the adhering of sand may be the result of steel penetration into the mould wall. The tendency of adhering is increased as the permeability of the sand increases. Higher density, i.e., lower permeability seems to counteract adhering. A denser sand may be obtained by using a more fine-grained sand or a sand with a wide grain distribution. It is furthermore possible that a—

within limits—low sintering point should be desirable because it might facilitate the formation of a liquid phase which would clog the voids in the mould surface and prevent steel penetration. The nature of the bonding clay seems, according to this investigation to be of no importance in this connection.

The buckling and scabbing tendency very markedly decreased with increasing strength of the medium coarse moulding sands investigated. The buckle formation seems to be caused by the increase in volume of the quartz grains when the mould is heated, especially by the sudden increase of 2.4% in connection with the transformation at 575° C. From this point of view it seems preferable to cast so rapidly that the mould face does not reach this critical temperature until the steel comes in contact with the surface. Among other factors that might be of importance in this connection, but of which we still know too little, the author especially mentions the deformation capacity of the sand.

It is stated that the only way to make full use of these results is to establish sand control in the foundry and to mechanise and standardise the sand preparation.

The time necessary to clean and chip the worst and the best test castings obtained during the investigation was finally studied. The saving in time in the best case compared to the worst was 82% for cleaning and 58% for chipping.

A programme for further research in this field is outlined in the concluding part of the paper.

Relining Lead Alloy Journal Bearings

By A. E. Wolfenden

PERFORMANCE and service life of composite bearings depends in large part on the strength of the bond between the antifriction metal lining and the bearing shell. A procedure is outlined for relining railway carriage journal bearings with standard lead-base bearing metal containing 3 to 5% tin, 8% antimony, and the remainder lead, which has been developed from many experiments involving the use of numerous fluxes, tinning solders, temperatures of both tinning and lining metal baths, the pouring and cooling rates of the lining metal and other variables. The results of these experiments were evaluated by means of bond strength tests taken from

bearings under production conditions. Service tests made on a large number of bearings substantiated the results obtained from the bond strength tests.

All unserviceable bearings returned for relining should have the linings melted out in a pot designed so as to expose the minimum of molten metal to the atmosphere. The temperature of the pot should not exceed 300° C., as overheating the metal causes oxidation of tin and antimony, and bearings cast from such Metal will be brittle and subject to failure by cracking. All melted-out metal should be cast into pigs for subsequent use in lining bearing shells. On removal from the melting-out pot, bearing shells should be immediately brushed clean of

From *Jernkontorets Annal*, 1945, 120, pp. 467-515.

From *Metals and Alloys*, 1945, 22, No. 1, pp. 81-84.

adhering lining metal, cooled, inspected for cracks, porosity and other defects, gauged and then rebored to expose clean metal surfaces before relining. Fluxing, tinning and relining operations should then be carried out within a few hours to prevent the freshly exposed metal surfaces becoming coated with a film of oxides and carbonates which resist the action of the flux and prevent the formation of a good bond.

In fluxing, acid zinc chloride solution gives the most satisfactory results and should be scrubbed on to all parts of the newly bored bearing surfaces to be tinned. Bearing shells should then be allowed to set for 1 to 1½ minutes before placing them, fluxed surface down, into the tinning bath. It is extremely important that the fluxed surface of all shells be moist when they are submerged into the tinning solder. A tinning solder containing 20 to 25% tin and 75 to 80% lead was found to have a higher bond strength with lead-base bearing alloys than high tin solders. Experiments have also shown that the temperature of the tinning bath should be regulated from 330° to 360° C., depending on the size of the bearing shell, so that 45 to 50 seconds are required to melt the solder that solidifies on the shell. At these temperatures no covering of flux or charcoal is necessary to prevent drying of the bath.

When tinned, the bearing shell should be removed from the bath within 1 to 1½ minutes after immersion, placed on a mandrel, radius end down, and the lining metal poured without delay. If the tinned surface of the shell is allowed to become solid before the bearing metal is poured, diffusion of the bearing alloy and tinning metal cannot occur, consequently the bearing will have a loose or very weakly bonded lining. The temperature of the mandrel has as great an effect on the physical properties of the bearing metals as does the pouring temperature of the bearing metal. A cool mandrel causes gas pockets and weak bonds due to the shrinkage of the lining from the shell, while a hot mandrel results in the formation of blisters on the lining surface, segregation of the metal, excessive shrinkage, low hardness, low compressive strength and brittleness of the lining metal. The pouring temperature should approximate to 330° C. and the bearing metal should be poured from one side of the bearing to the other in a slow steady stream without interruption, using a self skimming bottom-pouring ladle. The

bearing should not be removed from the mandrel until the lining has completely set.

By following the above procedure, bearings can be produced which consistently have a bond between the bearing metal and the shell of more than sufficient strength to withstand oil pressures of 5,000 to 6,000 lb. per sq. in., which are developed by radial and end impact thrust loads on the lining bond. High bond strength not only prevents failure of the bearings by progressive separation of the lining

from the shell, but also eliminates entrance of oil between the lining and the shell through radial cracks in the lining. Formation of areas subject to boundary lubrication and excessive heating, due to the lower conductance of heat through the intervening layer of oil are thus prohibited. Good practice in relining should yield bond strengths which exceed that of the lining metal, and with lead-base alloys should average 8,000 to 1,000 lbs. per sq. in.

A Variable Cycle Alternating Immersion Corrosion Testing Machine

C. H. Mahoney, A. L. Tarr and K. A. Skeie

AN apparatus was designed which is capable of variable but accurately controlled immersion or drying cycles, in which the atmosphere to which specimens are exposed during drying can be circulated under predetermined temperature and humidity conditions, and which is also capable of testing approximately 50 samples simultaneously. Later tests with the equipment indicated that circulation of the atmosphere is not necessary for most testing requirements.

This variable cycle apparatus tests up to 48 specimens or clusters of specimens in separate glass solution containers which are heated by a common thermostatically controlled bath. The specimens, suspended from a rack by means of glass stirrups are raised and lowered alternately by a sprocket chain attached to a motor-driven cam. The immersion and aeration periods are automatically controlled by means of independent time switches which permit variations in the periods ranging from a few seconds to ½ hour. The specimen rack is so designed as to prevent pendulum action of the specimens without introducing undue rigidity which might cause the glass stirrups to break on sudden starts and stops of the rack. The rack can also be pulled from the testing cabinet to permit rapid examination and handling of specimens.

A special feature of the apparatus is the wide range of cycles which can be obtained by means of the time relays used to control the immersion

and draining phases. Each relay has a coarse adjustment made by placing a pawl in one of four notches, located under the right-hand corner of a calibrating plate, and a fine adjustment made by rotating a pointer on the calibrating plate. For satisfactory operation the relay should not be set for a shorter time interval than ½ sec., Table I. Another feature of the apparatus is the provision of separate beakers for each specimen or cluster of specimens. This offers a wide scope of test possibilities as duplicate samples may be tested simultaneously in a number of corrosion media, samples of a number of different alloys may be tested without fear of cross contamination by the products of corrosion from adjoining or other specimens, and the unit is admirably suited for control testing to determine if successive lots of the same material have similar corrosion resistance properties. The 1000 ml. capacity beakers used in the apparatus are equally suited to both disc specimen and physical test bars being approximately 3½ in. in diameter and 7 in. deep. The volume of corroding solution to specimen area provides a reasonably high ratio for most test specimens.

TABLE I.
POSSIBLE RANGE OF ALTERNATE CYCLES
ON 60-CYCLE CURRENT.

Location of Pawl	Minimum	Maximum
Inner Notch ..	½ sec.	29 sec.
Second Notch ..	½ sec.	2 min., 14 sec.
Third Notch ..	½ sec.	8 min., 48 sec.
Outer Notch ..	½ sec.	33 min., 30 sec.

From *Bulletin Amer. Soc. for Testing Materials*, 1945, No. 133, pp. 16-17.

Tellurium

TELLURIUM is one of the rarest of the rare metals as far as composition of the earth's crust is concerned. It ranks in abundance with rhodium or gold. And yet metallurgists are more familiar with the occurrence and typical properties of tellurium and of certain of its compounds than they are with rare metals such as scandium or hafnium, over one hundred times as prevalent as tellurium. The reason for this familiarity with tellurium is based on the fact that the element is met with in nature and also in industry as a "concentrate." In nature there are located, in California, Colorado, Transylvania and in other parts of the world, commercial deposits of gold and silver combined with tellurium. The only combined gold in nature is gold telluride, calaverite, AuTe_2 . There are also the minerals sylvanite (AuAgTe_2); petzite (AgAu_2Te); and hessite, Ag_2Te .

The other concentration of tellurium occurs in the electrolytic copper and electrolytic nickel industries. Tellurium, together with selenium and other elements, accumulate in the anode slimes. It was not until about 15 years ago that tellurium entered the regular, commercial, metal market.

Tellurium was discovered in 1782, by the Austrian chemist, Franz Josef Müller von Reichenstein. Sixteen years later the discovery was confirmed by Martin H. Klaproth, who called the new element tellurium.

Tellurium is a gray, hard metal that melts at 452°C . and boils at 1390°C . (in hydrogen). The specific gravity is 6.25. Chemically, tellurium is comparatively inactive. It does not react with water either at high or at low temperatures, or with weak acids or weak alkaline solutions. Heated in contact with one of the heavy metals, it will react to form tellurides of zinc, cadmium, tin, lead, iron, cobalt, nickel, copper, silver, gold, etc. Tellurium is precipitated out of solutions of tellurium dioxide by bubbling SO_2 through the solution; a brown powder is obtained.

Tellurium metal is readily deposited from alkaline (sodium tellurate) solutions as well as from hydrofluoric acid solutions (F. C. Mathers and H. L. Turner *Trans. Electrochem. Soc.*, **54**, 293, 1938). An alkaline bath is employed by one of the large copper companies as the final step in the recovery of tellurium.

Tellurium is undoubtedly one of the most interesting metals from an electrochemical point of view. About 40 years ago Max LeBlanc carried out an experiment with two tellurium rod electrodes immersed in a normal solution of potassium hydroxide. Upon electrolysis (d. c.), both the anode and the cathode went into solution. No tellurium dissolved upon substituting a.c. for d.c. Le Blanc concluded that, with d.c. tellurium dissolved at the cathode forming divalent, negative ions (Te^{--}); and at the anode it dissolved forming quadrivalent positive ions (Te^{++++}). Equilibrium exists in solution between these ions and tellurium metal: $3\text{Te} = 2\text{Te}^{--} + \text{Te}^{++++}$.

In his classic researches on "Arc Images in Chemical Analyses," Wm. R. Mott (*Trans.*, **37**, 677 (1920)) observed a bluish-green arc stream and, upon addition of sodium carbonate, Te gave a dark green colloid solution as against a red solution for selenium. A. C. Krüger and Louis Kahlenberg (*Trans.*, **58**, 125 (1930)) studied the effects of oxygen, hydrogen, nitrogen, helium, and argon upon the electropotentials of tellurium, as well as of other metals, in neutral, alkaline, and acid solutions. They concluded that "the presence of a gas affects the potential of any metal. The effect is highly specific and varies with the nature of the gas, of the metal, and of the electrolyte."

The metallurgy involved and the methods employed in the removal of tellurium from the copper slimes are briefly presented by S. Skowronski and M. A. Mosher (*Trans.*, **61**, 113 (1932)).

U. C. Tainton (*Trans.*, **61**, 123 (1932)) found that the presence of minute particles of tellurium in the zinc leach solution acted as a catalyst for the precipitation of cobalt, a very objectionable impurity in the electrolyte used in the electro-winning of zinc.

F. H. Getman studied the tellurium electrode, $\text{Te} \rightarrow \text{Te}^{++++}$ (*Trans.*, **64**, 201 (1933)) and found the normal electrode potential to be -0.5682 volt.

In his review of progress made in electrolytic refining of metals during the decade 1930-1940, M. F. W. Heberlein (*Trans.*, **77**, 123 (1940)) refers to the increased production of tellurium, notably in Canada and Sweden, advancing the metal from the group of rare elements."

K. Dengg refers to experiments of

Thomas Edison, Inc., upon the addition of 0.08% Te to storage battery grids. A decided improvement in the age hardening of the battery grids was noticeable (*Trans.*, **79**, 305 (1941)).

R. C. Newton and N. H. Furman (*Trans.*, **80**, 23 (1941)) describe the persulphate oxidation of tellurium and suggest that the method should be advantageous in critical studies of the residual amounts of As, Sb, Se and Te in electrolytic copper suspected to be contaminated.

Tellurium has been used as an addition agent for bright nickel plating solutions (V. H. Waite, *Trans.*, **80**, 573 (1941)).

Among commercial applications of tellurium are the use of tellurium in place of sulphur in vulcanising rubber. The product is much tougher than the sulphur-vulcanised rubber. Tellurium-rubber covered cable is a regular article of commerce.

Most important of the applications of tellurium are those in metallurgy, and outstanding among these is the addition of 0.1% tellurium to lead, rendering it more resistant to corrosion, besides making it tougher and stronger mechanically, as well as more highly resistant to fatigue. Whereas pure lead has a fatigue resistance of 403 lb./sq. in., the tellurium-lead registered 1,120 lb./sq. in. The grain structure of tellurium lead is extremely fine and uniform in contrast with the rough, coarse, crystalline structure of ordinary lead.

Spot Test for Aluminium and Manganese Bronzes

A U.S. Bureau of Mines report, "Spot Test for the Separation of Aluminium Bronze from Manganese Bronze," describes a means of separating these bronzes that is quick, accurate and generally well adapted to plant use. A small area on the surface is cleaned of all dirt, scale and grease, by grinding. This freshly prepared surface is sprayed with an acid solution by means of an atomiser bottle. After the acid has reacted for several seconds, a drop of indicator solution is introduced from a medicine dropper. A grayish purple spot is produced with manganese bronze whereas a greenish yellow spot appears if the alloy is aluminium bronze. The quick appearance of the characteristic colour permits many tests to be conducted in an hour.

From *Bulletin Electrochemical Soc.*, May, 1945.

Acid solution and sprayer: A sulphuric acid solution of 1 part H_2SO_4 and 2 parts water by volume is most satisfactory; a weaker solution intensifies the colour of the aluminium bronze spot and a stronger solution intensifies the manganese bronze spot. An all-glass atomiser can be easily made by connecting a rubber pressure bulb to the glass tip of a medicine dropper and mounting the tip directly above a glass capillary tube which

extends through a cork into the acid. Indicator solution: Only one drop of indicator is required per test and hence 55 cc. of solution goes a long way. Dissolve 4 gm. of mercuric chloride ($HgCl_2$) and 4.5 gm. of ammonium thiocyanate (NH_4CNS) in 55 cc. of water. The addition of 0.01 gm. silver nitrate and 0.75 gm. of ammonium persulphate ($(NH_4)_2S_2O_8$) makes the indicator work somewhat better but is not necessary.

spent liquor, containing caustic soda and some alumina, is returned to the digesters.

By such a cyclic process it is possible to treat bauxite containing 10 to 18% silica and recover 85% to 90% or more of the alumina, whereas the Bayer process alone effects an ordinary recovery of 80% to 85% from high-grade bauxites, and only 70% or less from low-grade ores.

(Re-treatment of waste has been carried out by the British Aluminium Co. for many years.—Editor.)

More Alumina from Bauxite by Sintering "Red Mud"

A SIGNIFICANT improvement in the Bayer process for the production of alumina from bauxite is the war-time development by the Aluminium Company of America of the Alcoa combination process. Its technical feature is the re-treatment of the "red mud" waste resulting from the Bayer process. Its economic importance is two-fold: It recovers additional alumina, and it makes possible the utilisation of low-grade high-silica bauxites.

In the Bayer process bauxite is digested under pressure with hot caustic soda solution, which dissolves the alumina and leaves the impurities, iron, silicon, titanium, as an insoluble filter residue known as "red mud." Because each pound of silica in this residue causes a loss of one pound each of alumina and soda, as insoluble sodium aluminium silicate, it has been desirable to use high-grade, low-silica bauxite. But such bauxite, containing less than 7% silica has not been freely available in the United States during the war; and the more plentiful low-grade domestic ores contain about 13% silica. The use of the latter in the Bayer process being wasteful, it became necessary to modify the standard process if low-grade ores were to be used.

A laboratory process for recovery of both alumina and caustic from Bayer plant waste, which had been developed by Aluminium Research Laboratories, was brought to the commercial stage and installed in four Bayer plants. The efficiency of the combination process is such that the proportion of alumina recovered from high-silica silica bauxite is higher, and the soda loss lower, than in the old Bayer process treating high-grade bauxite. In the new process the "red mud" is

mixed with ground limestone and soda ash, and sintered in a kiln at a temperature of 1,800° to 2,000° F. (980° to 1,090° C.) to break up the sodium aluminium silicate. The limestone and soda ash are adjusted in amount so that there is a slight excess of lime over that necessary to combine with the silica to form dicalcium silicate, and a slight excess of soda over that necessary to form sodium aluminate with the alumina. The 250 ft. (76 m.) coal-fired kilns contain festoons of chains at the feed end, which break up the slurry as it dries and prevents the formation of balls and rings. The soft, friable sinter is then ground and leached with water to produce a solution of sodium aluminate and caustic soda containing the major part of the alumina and soda in the "red mud." After filtering and washing, the residue—now known as "brown mud"—is run to waste. The filtered solution, containing the sodium aluminate and caustic soda formed in the sintering operation, is combined with the spent liquor of the standard Bayer process and returned to the digesters for the treatment of fresh bauxite. The sintering and leaching operation does not effect complete separation of silica, and a small part passes back to the digesters, possibly in colloidal form, where it again passes into the "red mud" with the insoluble portion of the bauxite charge. The remaining steps in the process follow standard Bayer practice. The clear solution of sodium aluminate is sent to precipitation tanks, where, by "seeding" with aluminium trihydrate and by slow cooling and agitation, crystalline aluminium trihydrate is formed. This product is filtered, washed and calcined to produce the pure alumina necessary for electrolytic reduction to aluminium. The

Nitrogen as an Alloying Element in Steels

By A. Black.

NITROGEN, which steelmakers have for years, considered highly undesirable, has recently proved itself a valuable addition to certain steels. All steel contains a very small, almost infinitesimal, amount of nitrogen picked up from the atmosphere in the smelting process, but the amount is too small to have any noticeable effect on the properties of the metal. Where present in fractional percentages, nitrogen has been found to have a most important effect on practically all chromium steels. The effect is most pronounced in the case of those containing over 11% chromium. Metallurgists believe that the nitrogen combines to form either chromium nitrides or iron chromium nitrides. When the ratio of nitrogen to chromium is below about 1 to 100, the nitrides seem to remain in solution in the steel at all temperatures. In the martensitic (or hardenable) type of stainless steels, the effect of nitrogen is like that of carbon in that it increases the hardness and tensile strength but, unlike carbon, it has little or no effect upon toughness or resistance to corrosion. The same is approximately true for the ferritic, non-hardenable 16 to 18% chromium steels. In the case of the 20 to 30% high-chromium steels, the effects of nitrogen are extremely marked. Here, the effect is to increase both the ductility and the strength. In the case of the 18 and 8 chromium-nickel austenitic, the addition of nitrogen has the effect of improving the tensile strength materially without impairing either the ductility or the corrosion resistance.

Mechanical Engineering, February, 1946.

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